SCIENTIFIC AMERICAN SUPPLEMENT. No 1693

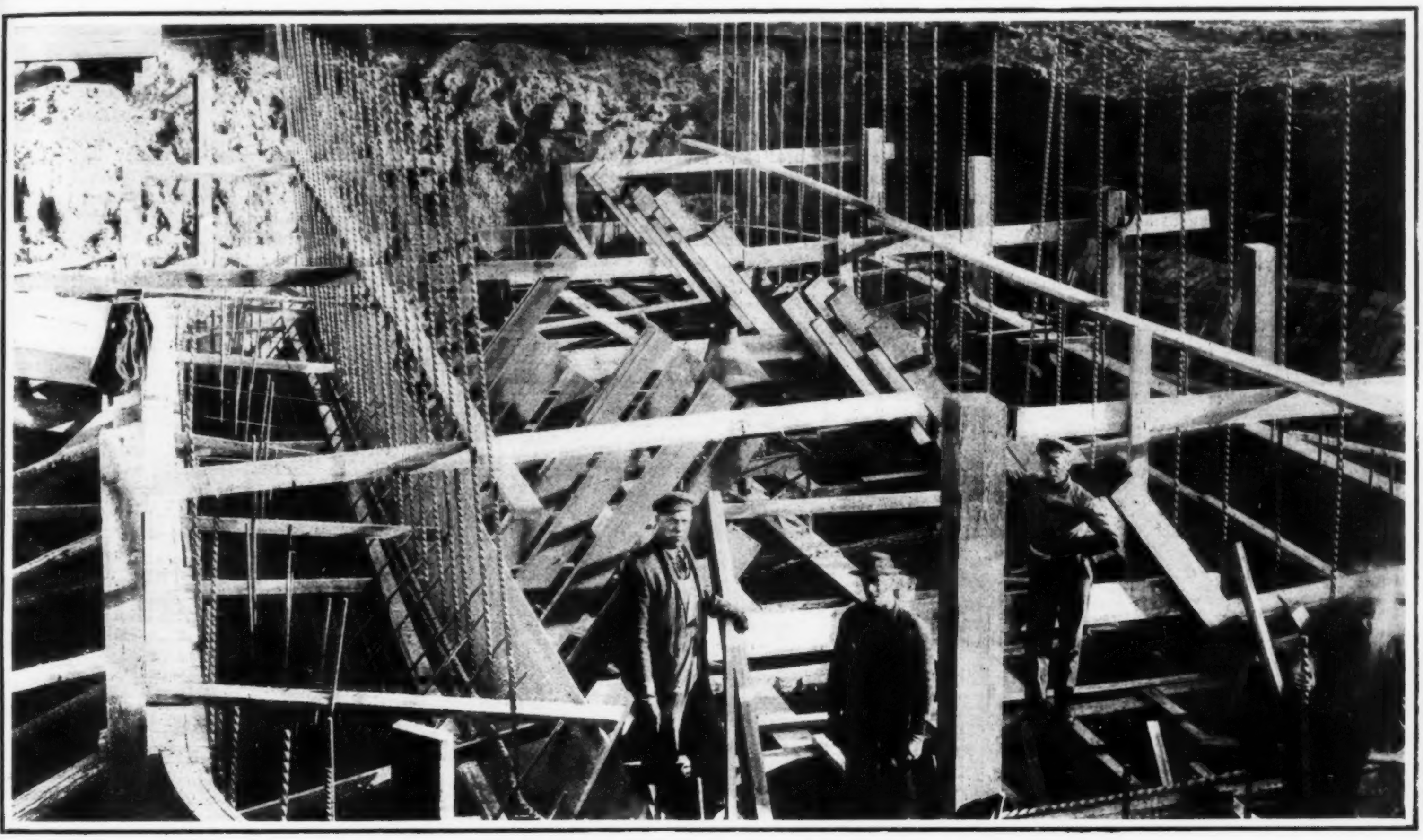
Entered at the Post Office of New York, N. Y., as Second Class Matter.

Published weekly by Munn & Co. at 361 Broadway, New York.
Charles Allen Munn, President, 361 Broadway, New York.
Frederick Converse Beach, Sec'y and Treas., 361 Broadway, New York

Scientific American, established 1845.
Scientific American Supplement, Vol. LXV., No. 1693.

NEW YORK, JUNE 13, 1908.

Scientific American Supplement, $5 a year.
Scientific American and Supplement, $7 a year.



THE SYSTEM OF REINFORCING STEEL RODS IN PLACE READY FOR THE CONCRETE.

THE MASSIVE CONCRETE SHAFT LEADING TO ANTHRACITE COAL MINE.

SINKING A CONCRETE MINE SHAFT.

SINKING A CONCRETE MINE SHAFT.

THE SIMPLE METHODS OF FORMER DAYS SUPERSEDED.

ACROSS the Susquehanna River from Wilkes-Barre, Pa., within a mile of the city, there is now being completed a piece of work by a method which has not before been attempted in the anthracite region. It is a striking illustration of the complexity of modern anthracite mining as compared with the simple methods of former days. This job is nothing less than the making of a concrete shaft wall above ground, and the gradual lowering of it to inclose a mine shaft. The concrete inclosure is 48 feet 10 inches long by 14 feet wide. Eventually the shaft will be divided, making in effect three separate shafts, one to accommodate two cages for hoisting coal, one for a pump and ladder way, and one for an upcast airway. It is at the Woodward Colliery of the Delaware, Lackawanna & Western Railroad Company, and known as the No. 3 shaft.

Though unusual as an engineering work, this method of sinking a shaft is chiefly interesting, perhaps, because it shows what a vast change in mining methods is brought about by the exhaustion of the veins which were comparatively easy to reach. The first anthracite coal was taken from the "outcroppings," where the coal strata came to the surface of the earth, and when this was no longer possible, the most accessible and thickest veins were next mined. At that time the aim was to get the greatest possible amount of coal for the least possible outlay, and little thought was given to advanced methods to prevent waste and conserve the future supply. All that is changed. The thick veins of coal lying near the surface have practically been exhausted in most of the anthracite region. Shafts were sunk to the thicker veins, and where there are thinner veins underlying, the shafts have to be sunk deeper to supply the demand for coal.

In order to mine the coal, it is necessary to have the openings over the roadways about 6 feet in height to accommodate the mules and cars, and as the thin veins vary from 2½ feet to 5 feet in thickness, enough rock must be removed to obtain this height.

The exhaustion of the thicker veins has caused a breaking of the overlying strata, which causes a large inflow of water. The pumping, the increasing length of haulage ways in the mines, the work of hoisting and ventilation, are far more serious problems than were encountered a generation ago. The cost of mining, consequently, is increasing with the difficulties.

In the century that has passed, since the utility of anthracite was discovered, its mining has developed from the production of a limited supply for local domestic uses to a vast industry supporting a population of more than a million people. Within the last ten years, the anthracite operators have revolutionized mining methods. They have introduced economies which at one time would have been scorned, but which are now recognized as being the part of wisdom and foresight. A vein of coal in a colliery is not opened to be abandoned as soon as the richer layers of coal have been mined. The colliery is operated with a view of obtaining all of the available coal. The operators recognize the fact that the supply of anthracite in the country is limited, and they are endeavoring to obtain a maximum yield per acre, realizing that the time is coming when every form of waste will be regretted.

It follows from the fact that the anthracite in the most available locations has been well nigh exhausted, that shafts must be sunk in more unfavorable and hazardous locations, in places where operations would never have been located in the earlier stages of mining. This is the case in the Delaware, Lackawanna & Western Railroad Company's Woodward No. 3 shaft. Its location is on the flat lands of the Susquehanna River, which are only a few feet above the normal level of the river, the water overflowing these flats nearly every year.

The character of the soil, combined with the proximity of the river, is what led the company's engineers to decide on a concrete shaft wall or caisson. There are layers of sand, gravel, quicksand, and clay overlying the rock. After excavation into this surface at any point, the water is found to maintain the same level as in the river. In sinking the shaft through this surface, it becomes even more difficult than it would be to put a shaft in the river itself. The use of any other method than the one employed would be much more hazardous to the maintenance of the shaft and the preservation of life.

In sinking the shaft, which was done by the Foundation Company of New York, it was first necessary to construct a steel cutting edge, generally oblong in shape with rounded corners. The length of this shoe over all was 59 feet 6 inches, and its width 28 feet. The outer extremity of the cutting edge consists of ½-inch steel, and is about 30 inches in height; and riveted to this on the inner side, about 8 inches from the bottom, is a horizontal steel plate, ½ inch in thickness and 24 inches in width, which answers for a shelf to support the concrete, which tapers inwardly to a thickness of 7 feet on the sides.

A pit was dug to a depth of about 15 feet. On the bottom, made perfectly level, was placed the steel cutting edge, which surrounded the location chosen for the shaft. Then molds for the concrete walls were made of wood, and laid upon the cutting edge, to a height of about 20 feet. When the concrete became sufficiently hardened, excavations were made from the center, and the dirt hoisted by means of a bucket. As the excavations progressed, the weight of the concrete walls gradually forced the cutting edge downward. As sinking progressed, more concrete was laid upon the top of that already hardened. In this manner the concrete walls made their own way through the surface. As fast as the concrete hardened under the lower section, the forms were removed, and another section of the concrete added to the top by the use of the same forms, thus continually adding to the weight.

Great care was required on the part of the engineers in charge to keep the concrete walls vertical, or in other words, to keep one part from sinking faster than another. This required constant watchfulness, and where one part was found to be sinking more rapidly than another, the excavation from the inside was increased or decreased accordingly. This process was continued until the walls reached a depth of 79 feet, when solid rock was encountered.

At the top the concrete walls extend from 15 to 20 feet above the ground, so that when the surrounding surface is under water, the shaft may be kept perfectly dry, the height of the walls being more than enough to protect the shaft from the highest water mark ever reached in the vicinity. When the cutting edge reached rock, the top of the rock was found to be somewhat uneven, and the space between the rock and cutting edge was securely calked by means of wooden wedges, to keep the interior of the shaft as dry as possible.

The concrete shaft walls above rock being in place, the rock was blasted out beneath the concrete walls to within about 2 feet of their outer edge, and to a depth of about 20 feet. Forms or molds will be laid from the solid rock about 20 feet below its top, up to the concrete walls. This space will also be poured with concrete, making the inner surface perfectly plumb and water-tight to this distance in the rock.

Then the quarrying of the rock for the shaft proper will be continued by local contractors. Before the Foundation Company have completed their job, the cost will have reached about $75,000. Three thousand cubic yards of concrete and 145 tons of reinforcing steel will be contained in the walls. The rock and sand used in this concrete work were obtained in the vicinity of Scranton, and the cement from New Jersey.

When the concrete portion of the shaft is completed, a total depth of about 100 feet will have been reached. The total depth of the shaft will be about 805 feet, at an estimated cost of $200,000, after which, at an additional expense, it will be necessary to install two large ventilating fans, one to be used in case of emergency. Each of these will have a capacity of about 350,000 cubic feet of air per minute; hoisting engines and pumping plants will also have to be installed before any coal will be mined.

The process of sinking has been in progress about six months, and it will require at least another year before mining operations can be started.

BUILDING THE CONCRETE FORMS INSIDE THE STEEL CUTTING EDGE.

BREAD.

By A. E. HUMPHRIES.*

BREAD is the outcome of remarkable commercial and scientific development. Fifty years ago Scotch shepherds, leading a life devoid of the creature comforts of advanced civilization, carried on their persons raw oatmeal as their "staff of life," principally because it was relatively so cheap. To-day, when oatmeal is 2d. ($0.04) per pound, dog biscuits 2½ d. ($0.05) per pound, and beefsteak 1s. ($0.24) per pound, the wheaten bread of commerce is delivered to our doors at prices ranging from 1d. ($0.02) to 1½d. ($0.03) per pound, according to its quality and the services rendered by the baker. Out of this small price the baker, the miller, with his elaborate and costly processes of cleaning and milling, the corn merchant, the shipowner bringing wheat from all parts of the globe, the farmer, and the numerous ancillary trades depending on him, have to earn a profit.

A rapidly increasing population has wanted bread both for a food and for an occupation to earn a living. No country has produced as much food as it can be made to produce. The population of the United Kingdom has increased by 50 per cent in thirty years. In the early seventies we produced about 55 per cent of the wheat consumed at home; nowadays we are producing only about 20 per cent. It would be interesting, but out of place herein, to inquire whether it would be possible to produce in this country all the wheat we require. The greatest quantity produced here was about 18,000,000 quarters in 1863; we want now in all, say, 32,000,000 quarters per annum. A great deal of land then under wheat has been diverted to other purposes, entailing a relatively lower cost of production. The sight of hills in Wiltshire laid out in artificial terraces, covered now by grass, producing indirectly food for man in reduced quantity at lower cost, is suggestive. That is typical of much. If the self-binding harvester, which rendered possible the growing of wheat in huge areas of virgin lands, had not been invented, or if large ships, some of them able to bring here in one freight at minimum cost as much wheat as many a county produces at one crop, had not been evolved by the progress of science, prices would have been much higher, and wheat-growing would have been commercially possible on soils and under conditions where no man dreams of raising it now. To a miller or a corn-merchant the striking prophecies of Sir Wil-

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liam Crookes as to the danger of an absolute scarcity of wheat presented no terrors. He, more fortunate than Frankenstein, laid his own monster by the prospect of increased crops, due to the discovery of a cheap form of nitrogenous manuring. This meant either that the increase in yield per acre would of itself repay the cost of the manure without an increase in the price of grain per quarter, or else that it would be possible to grow increased crops of grain by the aid of fixed atmospheric nitrogen, if a rise in the price of wheat would allow the farmer to buy the manure.

If the former alternative be the correct one—and it is likely to be so—the consumer with an income of say 4s. ($0.96) per week per head of his family would have reason to bless the scientist in years to come; but if the latter alternative be the way in which this advantage is to be obtained, even then his fears were not at all formidable. For to the lay mind of a miller or corn-merchant the problem did not seem to be whether the world could grow enough wheat for the actual needs of its inhabitants, but whether it would grow enough at prices equal to 30s. ($7.20) per quarter delivered at a British or continental port—two essentially different propositions. At an average of 35s. ($8.40) it is certain that more land would be placed under wheat; still more at 40s. ($9.60), much more at 45s. ($10.80), very much more at 50s. ($12.00). Price is then a most essential point to be borne in mind by the scientist as well as by the practical man—indeed, the triumphs of science in connection with bread are mostly connected with it. To scratch virgin and fertile soils and produce from eight to twenty bushels of wheat per acre in the new countries of the world, when the average yield in England is over thirty bushels per acre, may be good business, but the scientific attainment does not appear to be striking. Indeed, though a great deal of valuable scientific work concerning wheat, flour, and bread is being done in these new countries, the most important scientific progress already made concerns the transit of the produce to the markets of the world, the development of railways and ships, the development of processes enabling the miller to clean the produce of slovenly farming, and the joint efforts of miller, baker, and yeast manufacturer in the production, from the many wheats supplied to us, differing greatly between themselves and from those which were available thirty years ago, of good bread at the extraordinarily but beneficently low prices now current. But though the most strikingly important scientific developments in connection with our bread supply concern mechanics, and lie in what may be described as the outer circle of its relationship, much important work has been done in the inner circle, and I want in this article to deal with the developments which are closely connected with bread itself.

Wheat and rye are the only cereals used for bread-making. The quantity of rye produced in Europe annually is approximately equal to that of wheat, and it is a fact worth mentioning that the growing of rye is confined almost exclusively to Europe. Indeed, the only countries in which a large rye crop is raised annually are Austria-Hungary, where it equals about two-thirds of the wheat crop, Russia, where twice as much rye is raised as wheat, and Germany, where the proportions are approximately twenty-five of rye to ten of wheat. Analyses stated in generic terms, such as starch, ash, and albuminoids, do not disclose the reason why barley, oats, and maize are quite unsuitable for bread-making, and why rye is relatively unsuitable in British estimation for it. The brewer or distiller knows quite well that any of these cereals can be fermented: their percentages of natural sugar indicate that clearly enough, and bread-making, as ordinarily practised, depends upon the production of gas by fermentation. If therefore the power of yielding gas by fermentation were the only index of bread-making capacity, any of these cereals would be suitable, but the fact that they are not so discloses at the outset a characteristic which is as important as, probably more important than, the power of yielding gas, and that is the power of retaining it within the dough when by fermentation it has been produced, so that the dough can be aerated and made when baked into the appetizing and digestible breads of commerce. Doughs made from the flours of barley, oats, and maize do not possess the power of retaining gas, and as a consequence are quite unsuitable for bread-making. Dough made from rye-flour possesses that power to only a limited extent, and accordingly occupies an intermediate position as an article suitable for bread-making. The difference between wheat and the other cereals in this gas-retaining power is generally ascribed to the fact that wheat contains gluten and the others do not, but Fleurent, as the result of two series of analyses quoted by Bruyning,* gives the percentages of gluten in rye, maize, and barley as higher than that of wheat. The percentages of gluten are not the same in various samples of the same cereal, and the one I am about to quote is much lower than the average of flour made from really strong wheats, but the table shows at a glance that the essential difference between the cereals lies in the percentage of gliadin which the gluten contains:

	Gluten in the Flour, Per Cent.	The total gluten contains: Gliadin, Per Cent.	Glutenin, Per Cent.
Rye	8.26	8.14	92.83
Maize	10.63	47.50	52.50
Rice	7.86	14.31	85.70
Barley	13.82	15.60	84.40
Buckwheat ..	7.26	13.08	86.92
Wheat	7.47	75.25	24.75

The apparent contradiction between those who say, for instance, that barley-flour contains no gluten and the analyses of Fleurent which are here given, arises probably from a difference in the methods of extraction. There is no necessity to account with certainty for the apparent contradiction; the essential points for present purposes are that wheat and rye are the only cereals used extensively for bread-making because the others are quite unsuitable, that their suitability or unsuitability depends upon their power to retain gas made in fermentation, and that this depends upon the presence in the flour of a substantial percentage of gliadin, a nitrogenous body of a sticky nature which when wetted becomes figuratively the cement in the concrete formed by the union of the two sister nitrogenous bodies gliadin and glutenin. For several years it was believed that the strength of flour depended on the ratio of gliadin to glutenin in the gluten, but though the presence of a large proportion of gliadin in the gluten is essential, the idea that variations in the relative strengths of flours were correlated with or depended upon the ratio of gliadin to glutenin therein has in recent years been proved to be fallacious.

In an article written for a British magazine purporting to deal with the modern developments concerning bread or bread-making in Great Britain, nothing more need be said about rye bread, for the quantity consumed in this country is exceedingly small. Practically all British bread is made from wheaten flour. Old men tell us that in their youth, when bread was dear and wages low, some of the best of wheaten offal (the generic technical name for the by-products consisting principally of husk, made in flour-milling) was used in times of scarcity for the making of common bread, or for mixing with the more costly flour with that object; but since food has become cheap, and wages in amount and purchasing power so much higher, the working classes, who are the large bread consumers, have become particular, almost fastidious, as to the quality of the bread they buy, so that, judged by its appearance, flavor, digestibility, and food value, modern bread is much superior to that which was in common use fifty or sixty years ago. There is a type of mind possessed by a large proportion of old people which lingers affectionately on days gone by and believes that many old things, including the bread made fifty years ago, were altogether superior to modern ones, and it is useless, perhaps cruel, to argue with such people, or to suggest that in those days they were healthy youngsters, with corresponding appetites, teeth, digestion, and habits, instead of valetudinarians or people satiated with good things. It is obviously impossible to produce now for actual comparison typical bread made fifty years ago, but enough is known to spoil the pretty picture which such a memory conjures up of the beautiful bread made half a century ago.

In a recent political controversy one heard of bread eaten with a spoon in those good old days, and though no one suggests that that was typical of all bread, or most bread, made in those days, specimens made from common English wheats damaged in the wet harvests of 1879 or 1902 came as reminders of what we might have to endure if we were now, as then, practically dependent on common wheats grown in our variable climate under extremely unfavorable conditions. They used to hear of alum in bread, and we do not, for the modern methods of curing inherent defects in our wheats by blending them with other sorts of different constitution, and modern methods of milling and baking, have come to the rescue and have made quite unnecessary the recourse to that injurious but effective remedy for damaged flours. Another remedy for bad quality in wheat which one no longer finds in use was the admixture of beans. In bad seasons millers used to grind old beans, and mix the flour with that made from wheat, so as to improve their product in the estimation of the baker. In Great Britain that is no longer necessary or desirable, and is not resorted to in any degree, although it is said to be done quite openly in some parts of the Continent. We are told that modern songs are not nearly so good as the old ones, but the critic of modernity appears to forget that he is pitting the average of modern work, good, bad, and indifferent, against the survivals of older times, and a great deal of grumbling at modern bread is done in the same way. Fifty years ago the very best was very good, the average was poor, the bad very bad. In these modern days we have eliminated the very bad—no one would buy it—and under the pressure of competition have learned to make use of a wide range of qualities in wheat and flour, producing therefrom, at minimum cost, flour and bread of excellent and by comparison uniformly good quality. The best bread to-day is superb, free from adulteration, dirt, and contamination.

The whiteness of modern bread is regarded in different ways by various people. The miller thinks it is largely due to his immensely improved methods of wheat cleaning, whereby absolute dirt and dark fungoid contaminations are more perfectly eliminated than they used to be, and to the comparative perfection of his methods of grinding and separating husk from kernel, whereby he obtains from wheat a flour consisting of practically pure endosperm. The baker thinks he has materially affected the color of his bread by learning thoroughly the use of modern yeasts and adjusting his methods of bakehouse treatment accordingly, to secure a much nearer approach to pure alcoholic fermentation than he used to do. But there seems to be in existence a sort of person who sees in extreme whiteness an evidence of adulteration, or of some nefarious practice. For that state of mind there is absolutely no excuse. Laws against adulteration are in active operation, and definite charges against bakers of adulteration are unknown. Others again, who peel their apples and oranges, are possessed with the idea that nature means us to eat the husk of wheat, and that in refusing to do so we are failing to use a most valuable source of real nutriment. To such a one the whiteness of modern bread is an evidence of misplaced ingenuity. The idea is based on the supposition that the food value of any article is indicated by chemical analysis, prior to its consumption. That leaves out of account the limited and variable digestive capacity of the consumer. If, therefore, the aid of the chemist be involved, he must do much more than analyze the food of the human being, and must ascertain the amounts and chemical constitution of the fæces and urine voided before the true food value of an article can be ascertained. This has been done in a most complete manner at the University of Minnesota under supervision of Prof. Snyder, so far at least as protein, fat, and carbohydrate constituents are concerned; and the results show conclusively that in the case of every type of wheat used the white flour of commerce yielded more nutriment to the body than wholemeal, or wholemeal less its broadest pieces of bran. Even when the bran was reduced to a fine powder mechanically, its addition to white flour lessened the digestibility of the whole when converted into bread. A good deal of work has been done to ascertain the digestibility of the mineral contents of wheat, but no definite conclusion has been arrived at, though Snyder has said that, "as far as phosphates are concerned, white flour contains sufficient to meet all demands." The miners of South Wales and the North demand and obtain whiter bread than the Londoner, and in the light of these carefully ascertained facts as to the real relative food values of white and brown bread, this preference for the whitest bread has science as well as practice to back it.

Almost all the bread consumed in Great Britain comes into the category of white bread. The degree of whiteness varies according to price and district, but the flour used in its manufacture represents an extraction from the wheats of commerce of say 70 per cent or less. One noteworthy fact in this connection is the small but almost constant proportion of wheat-meal breads consumed. An exceedingly small number of people eat a little occasionally, and so provide themselves with a pleasant change in diet, perhaps with a mild aperient. Basing an opinion upon the amount of trade done in wheat meals by millers, I do not think that more than 1 per cent of the bread consumed in England comes into the class of wheat meals of various kinds or degrees of fineness. In recent years a demand has been created for germ breads. The best known of these is Hovis. They are not wheat-meal breads. The percentage of germ in wheat—the yellow oily part found at the thick end of a grain of wheat, in which alone, as its name implies, is the germ of future wheat plants—is about 1½ per cent. It contains active ferments, and in its raw state is far better out of flour than in it. It is not difficult to keep it out of flour in milling, but owing to the technical difficulty of separating it free from the husk of the wheat, millers only extract as a separate product say ½ per cent of the wheat ground. The makers of various germ meals cook it, and so destroy the ferments it contains; and, having done so, mix it with the ordinary flours of commerce in the proportions of say 75 per cent flour to 25 per cent cooked germ. The percentages of oil and albuminoids contained in raw germ are high—about 8 per cent and 27 per cent, respectively—and a human being can digest it satisfactorily; but it is obvious that so long as makers of germ meals or bread use a proportion of germ so very much in excess of that which is extracted in milling, only a very small proportion of the population can be fed on germ bread.

(To be continued.)

* La Valeur boulangère du Froment, page 67.

ELEMENTS OF ELECTRICAL ENGINEERING.—XIX.

MEASURING INSTRUMENTS FOR DIRECT CURRENTS.

BY A. E. WATSON, E.E., PH.D., ASSISTANT PROFESSOR OF PHYSICS IN BROWN UNIVERSITY.

Continued from Supplement No. 1691, page 342.

OERSTED's discovery, in 1819, that a current of electricity would deflect a compass needle, was at once recognized as offering a means of comparing or actually measuring the strength of the current. Evidence of the activity of scientists in trying to find the law of the current flow is recorded in the writings of that period, and by the actual finding of the law by Ohm, and its publication in 1826.

For fifty years from that time, the "galvanometers" built on Oersted's principle were the only kind, and took on many forms, as can readily be seen by reference to almost any book on physics. For detecting the presence of a current, without any attempt to measure its exact strength, the needle was about the size employed for coarse sewing, and was suspended by means of a few parallel silk fibers so as to swing over or within a coil of many turns of fine wire. Still higher sensitiveness was secured by employing a pair of needles, the north pole of one directly over the south pole of the other; one needle was within the coil, the other above it. By this device, the directive effect of the earth's magnetism was nearly counteracted, and the needle was quite ready to be deflected by indefinitely small currents. Entire independence of the earth's magnetism is impossible, for the reason that no two magnets can be made exactly alike; further, such independence is undesirable, or the needle would have no particular position of rest. When thus nearly neutral in position, the combination is said to be "astatic," or with a Latin rather than a Greek prefix, "non-static."

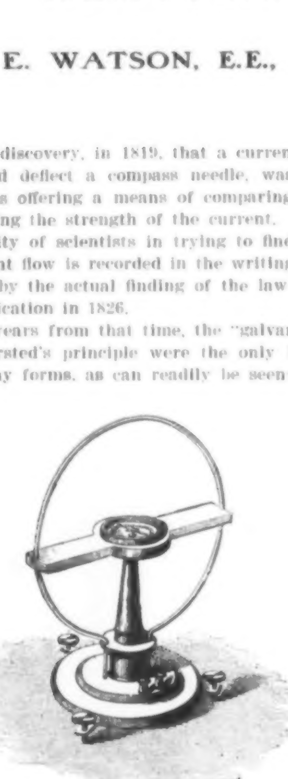


Fig. 91.—Simple Tangent Galvanometer.

With such arrangements, the most sensitive sort of instruments can be made, and practically typified by these designed by Lord Kelvin, then Sir William Thomson, for the Atlantic telegraph cables. With the feeble currents alone permissible, direct observation of the needle was impossible, and recourse was had to the movement of a spot of light as reflected from a tiny mirror attached to the needle. In fact, the method of construction was to use a mirror only about three-eighths of an inch in diameter, and to stick the little magnets on the back.

For most purposes such galvanometers are altogether too sensitive, and are so disturbed by the jarring of their mountings or by too strong currents as to have few practical applications. One less delicate form, consisting of but few turns, or often of only one turn, of large wire, with a short and stocky magnet suspended in the center, is of very great practical value. It is called the "tangent" galvanometer, and until the present constructions of portable instruments were devised, it offered almost the only means of measuring currents of considerable magnitude and in readily computed units. In fact, the present current measurers, or ampere meters, or "ammeters," as they are called for short, depend, for their ultimate calibration, upon reference to an instrument of this sort.

A simple model of the tangent galvanometer is given in Fig. 91. A single loop of copper wire has its terminals brought out to binding posts, and in the center is a short magnetized needle, provided with longer pointers and a scale divided into degrees. Some improvements could be made by letting the coil more nearly complete its circle, and by suspending the needle by a silk fiber from the upper portion of loop. Long and almost weightless pointers can be provided, in a home-made instrument, by use of straws. When current flows in the loop, lines of magnetic force are established in the region of the wire, in curves of increasing radius, but as the center is approached, the lines act nearly perpendicular to the plane of the coil. If the needle is short, it will be acted upon by these central lines, and the law of the tangent be approximately realized.

To use the instrument, the coil is moved so that the plane coincides with the direction of the needle—not necessarily with that of the pointer. The needle then points directly at the loop. Care must be taken to have no other magnetic fields present, and for extreme accuracy the instrument should be in some structure quite apart from others, and free from iron pipes or beams. The force of the current that would then deflect the needle will depend upon (*a*) the length of the wire, (*b*) the distance from the needle, and (*c*) the strength of the earth's magnetic field at that place. For a single turn of wire, the first quantity will be $2\pi r$ where r is the radius of the coil, in centimeters (1 sec. = 2.54 centimeters) or for n turns, $2\pi nr$; the second will be r, with the force falling off as the square of this distance, and the third denoted as H, can be determined from magnetic charts, or from inquiry of the government geological survey. For Providence, R. I., and vicinity, the value is about 0.179, that is, there is a horizontal force of the earth's magnetism amounting to 0.179 of a dyne. Since the force of gravity acting on a gramme, called its weight, is 981 dynes, and a gramme is only about one-thirtieth of an ounce, it is seen that the magnetic force is very small. In "absolute" units (ten times as large as the ampere) the equation becomes,

$$\text{Current} = \frac{r}{2\pi n} H \tan a.$$

By this it is seen that the means are provided for making an ammeter, by merely measuring the coil itself and observing an angle of deflection. Reference to a table of tangents is necessary, and a simple multiplication; but if not too great deflections are caused, a reasonable degree of accuracy is possible. Forty-five degrees would be a safe limit, and since the tangent of this angle is 1, the interpretation is very simple.

A numerical example might not be inappropriate. Suppose a coil had a single turn, 10 sec. in diameter; (for this case the needle should not be over ¾ sec. long). In centimeters the radius would then be 12.7; $2\pi = 6.28$, and the division indicated will give a quotient of 2.02; multiplying by 0.179 then gives 0.361; if a deflection of 45 deg. is produced, the current flowing will then be 0.361 absolute units, or 3.61 amperes. Any other deflection, say one of 19 deg., will represent a less current in the relation the tangent of 19 deg. bears to that of 45 deg.: tangent of 45 deg. = 0.34, and $0.34 \times 3.61 = 1.23$ amperes. A tangent galvanometer can thus be used to determine a sufficient number of the principal graduations of some commercial or portable ammeter, or at any time to check the divisions of such an indicator.

It is proper to admit that a high degree of accuracy with a tangent galvanometer involves many tedious corrections in the estimate of the dimensions, the distortion of the earth's field due to the presence of the magnetized needle, and in the errors of observation of the deflections, and consequently in a well equipped laboratory other methods would be preferred; but the instrument just described was the first one for the purpose, and for many years was the only available one. It still has value for its simplicity and cheapness. Amateurs and students would find great educational advantage in making and using one.

Fig. 93.—Wall Form of D'Arsonval Galvanometer, Fitted With Mirror and Telescope and Scale.

In consequence of the serious limitations of the suspended needle type of instrument, principally by interference from exterior magnetic fields and instability of its pointer, another form has been devised that in a high degree fills the conditions of a perfect instrument. This was invented by D'Arsonval, and consists essentially in reversing the arrangement of the earlier types; for instead of suspending the magnet and letting the coil be the stationary member, he made the coil very light, and connected it by delicate conducting wires, while the magnet was strong and of horse-shoe shape, fixed rigidly to the base. Entire independence of the earth's field was therefore obtained, and the movable coil was situated in such a relatively intense artificial field, that even minute currents would produce sufficient force to twist the suspending wires, and produce readily observed deflections. Fig. 92 at *a* shows the scheme. In actual dimensions the straight portions of the magnets are about 4 inches long, with the poles 1½ inches apart. A cylindrical chunk of soft iron, 1¼ inches in diameter, and 1¾ inches long, is rigidly attached to a post, and nearly fills the interpolar space, thereby improving the magnetic path. The little coil is wound of several hundred or thousand turns of No. 36 or finer wire, in a belt about ½ inch wide and 1/16 inch thick, and of such a size as to give internal and external clearances. After winding, the coil is bound with thread, and filled with shellac, so as really to be quite stiff, without any additional support. The terminals of the winding are attached to pieces of sheet metal pinched onto the coil, and thus provide substantial means for

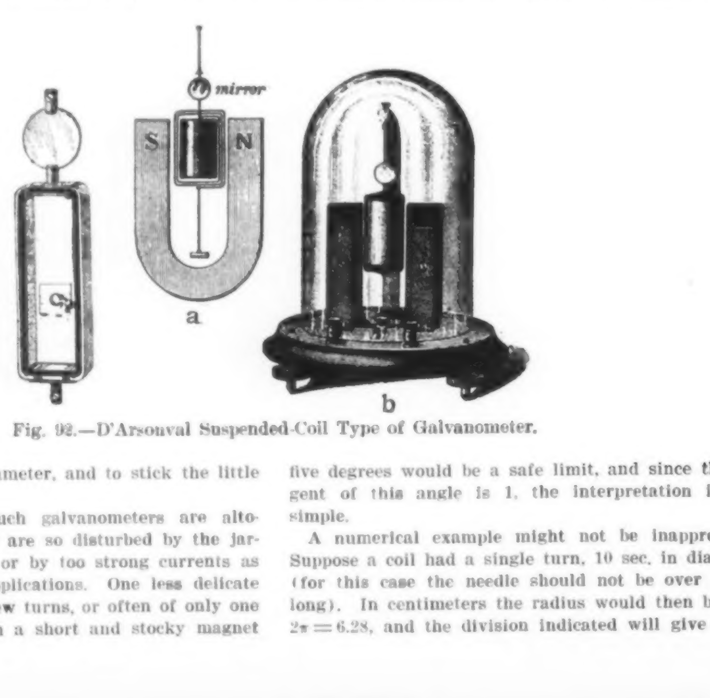


Fig. 92.—D'Arsonval Suspended-Coil Type of Galvanometer.

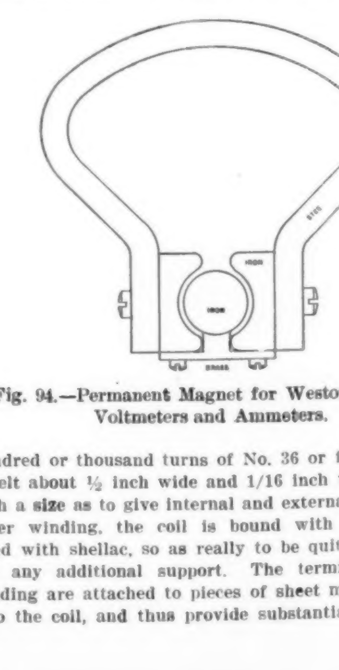


Fig. 94.—Permanent Magnet for Weston Form of Voltmeters and Ammeters.

soldering the fine flat suspending and supporting wires, of silver or phosphor-bronze. Some little tension is put upon these wires, whereby the coil is kept from swaying and hitting the poles of the magnet. These two wires represent the terminals of the circuit, and are to be connected to the source of the current. The construction is very delicate, and the coil will move its entire limit with an exceedingly small current. Fig. 92 at *b* shows the complete form, as commonly found in laboratory equipments. Such delicacy has been attained in the making of them for submarine telegraph lines, as not only to detect the currents, but to operate recording receivers. Any skillful amateur could readily make one quite serviceable for a large variety of experimental or commercial purposes. In a laboratory great preference is shown for small angular deflections, and with suitable devices for observation, the readings are then rather more accurate than with simple direct means of looking at a pointer. This is accomplished by mounting a little mirror on the coil, as shown in Fig. 92, and observing the image of a scale in a short-vision telescope. Fig. 93 represents a self-contained form of the D'Arsonval galvanometer, adapted for mounting on a wall, and fitted with such accessories. The scales are usually 50 centimeters in length, and have the centimeter graduations on cardboard or celluloid on the inner face of the wooden strip; light from the windows, or from a specially located lamp, illuminates this scale, and certain figures reflected from the mirror can be seen in the telescope. In consequence of the angle of incidence equaling the angle of reflection, the apparent movement of the figures on the scale, produced by movement of the mirror, is double the actual movement. By dividing the deflection on the scale by the distance of the scale from the mirror, the tangent of twice the real angle is found.

Such instruments are much sooner brought to rest than those having a suspended needle, and the zero point on the scale is readily maintained. Movements that are quite "dead-beat," that is, free from all oscil-

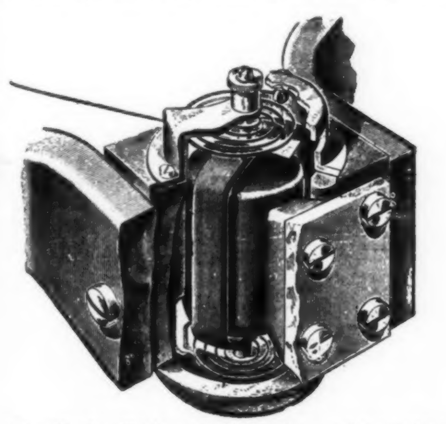


Fig. 95.—Moving System of Voltmeters and Ammeters.

lations, can readily be secured by the addition of "dampers" of sheet copper placed inside or outside the coils; these, being locally closed circuits, will allow, as soon as motion takes place, for the production of induced short-circuit currents, and to maintain their flow energy must be supplied; and as the only source of energy, after the first swing, comes from the inertia of the parts, the motion quickly ceases. In Fig. 92 at *c* a coil is shown on a larger scale, equipped with both internal and external dampers. It is the construction used for the galvanometer represented in Fig. 93. With such simple provisions, entirely free from mechanical friction, the act of sending a suitable current through the fine wire starts the coil moving with a moderate velocity, but diminishing as the goal is reached, and then without swinging by it gracefully comes to rest at the right place, and at the opening of the circuit, the coil returns to its normal position with a freedom from pendular vibrations as if an actual stop was struck.

With instruments thus responsive to meager currents, the next thing is so to arrange the apparatus as to measure actual electromotive forces and currents of indefinitely large magnitudes.

A voltmeter is an instrument that measures a current, to be sure, but a small one, and that proportional to the pressure. If the pressure is high it is certain that to connect the galvanometer directly, would mean its instant destruction, therefore the simple expendient is adopted of winding a large external resistance and connecting it in series with the fine wire coil. The greater the electromotive force to be measured, the greater must be this resistance, and the particular value for each instrument must be determined experimentally. The same instrument can be provided with several such resistance coils, and allow for use in measuring quite a range of pressures. Each resistance would mean that the galvanometer reading should be multiplied by a certain number, and the result be a certain number of volts.

An ammeter indicates the full strength of the current, but plainly, the current passable by the fine wire of the little coil is almost infinitesimal, therefore the greater portion must be taken through a suitably low resistance by-pass, or shunt. The case is like that of a river, with a small canal connecting two points quite close together; through the canal there would flow a current proportional to the main current in the river. The electrical case may at first afford grounds for suspicion that the device is not reliable, but entire dependence must be placed upon its accuracy. Divided

Fig. 96.—Weston Voltmeter With Double Scale.

currents follow the rigid law of flowing in paths in measure inversely proportional to the respective resistances. Therefore, however large the current, or however delicate the galvanometer, the measurement can always be made by providing a shunt of low enough resistance and large enough current carrying capacity. Of course accuracy of measurement is dependent upon the shunt keeping a fixed resistance, so that if heated by the current, it will still take its due proportion. Ordinary metals increase their resistance about 0.4 of 1 per cent for every degree Centigrade rise of temperature, hence recourse has been taken to alloys that are less affected in this particular. German silver was once the favorite material, but experience has proved that this mixture suffers deterioration and change of resistance. Different manufacturers have developed special mixtures, with attempts to keep the composition secret, but chemical analysis always reveals the facts, though not the particular methods of mixing. It seems that zinc is the disturbing element in ordinary alloys, and the best behaving resistances are those made without it. Silver, platinum, manganese, and tungsten are to be found in some of the more recent products of the instrument makers.

The description of the laboratory form of D'Arsonval galvanometer, and the principle of the high series resistance for the voltmeter and the low resistance shunt for the ammeter has been carried to an apparently undue length, but only to prepare the way for the highly convenient and practical forms adopted or invented by Weston. Soon after the above form was devised, Weston perceived that it offered the best means of providing portable and station-switchboard instruments. It is hard now to realize the dearth of satisfactory and accurate instruments for following the operation of dynamos until this inventor supplied the lack. Weston was the designing engineer for the United States Electric Lighting Company, with a factory in Newark, N. J., since purchased and largely developed by the Westinghouse Company, but he withdrew from that field and devoted himself entirely to the making of this particular type of instruments. Such success attended his efforts, that in spite of their high price, the voltmeters and ammeters from his works were everywhere in demand, and were adopted as standards of measurement.

Weston put the permanent magnet in a horizontal

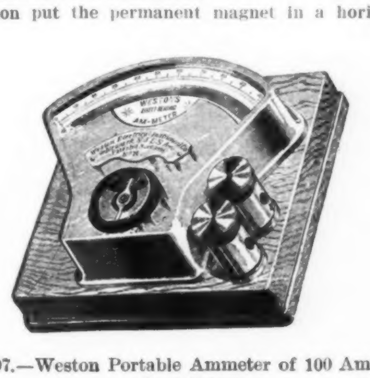


Fig. 97.—Weston Portable Ammeter of 100 Amperes Capacity.

position, fitted its ends with poles, resembling those on a dynamo, attached pivots to the coils, and supported them in jeweled bearings. Aside from the fact that jewels are in themselves insulators, the loose contact of pivots would be intolerable for electrical contacts, hence provision for getting current into and out of the coil had to be found in some other way. This Weston did by fitting each of the pivots with hair springs, and it was the double function of these springs to provide the electric path and the mechanical resilience that constituted the gist of the patent. Though continually contested in the courts, the decisions were finally in Weston's favor, but the patent expired in 1905.

A view of the particular shape of the magnet employed by Weston is given in Fig. 94. The crevasse in which the little coil moves is only about one-sixteenth of an inch wide, and in such a short air gap, the field of force is so uniform that deflections are directly proportional to the current flowing, therefore giving direct readings on the scale without recourse to tangents or any other functions of angles. The section of the steel is about ¾ x 1¼ inch, and the polar space about 1¼ inches in diameter and in axial length. In keeping with the principle that long magnets are stronger and more permanent than short ones, the shape is purposely spread out, rather than in the simple U form. The short air gap is also conducive to permanency. In order that the instruments preserve their accuracy for a long series of years, it has been found necessary to "age" the magnets by artificial means, and this process is by no means the least important item of the manufacture.

Very old magnets have been found to possess a high degree of permanency. It is certain that there is some connection between magnetism and molecular rigidity, for hardness of the steel is a prime condition of the retention of any magnetism. The tempering of steel tools, after the process of hardening, somewhat relieves the extreme rigidity, and this tempering is done by a moderate heating. Similarly, heating a magnet removes some of its strength, but singularly, the part is left more permanent. By climatic changes, old magnets have been heated and cooled many times, and by the gradual relief of unstable conditions, the part of the magnetism remaining has reached a definite

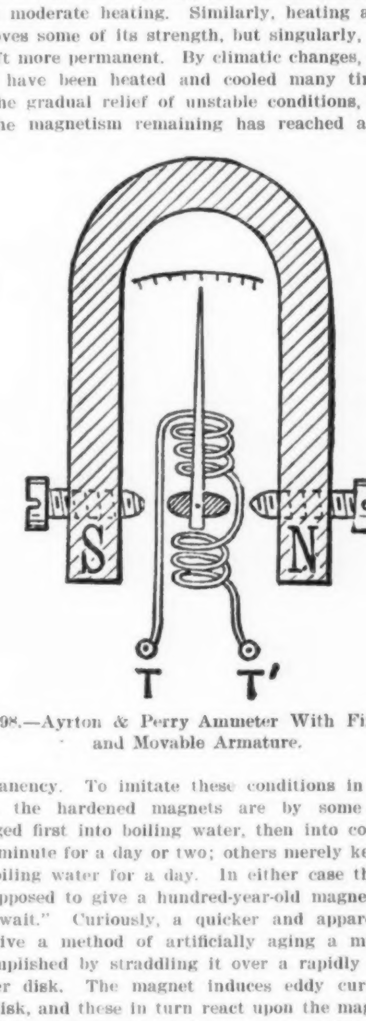


Fig. 98.—Ayrton & Perry Ammeter With Fixed Coil and Movable Armature.

permanency. To imitate these conditions in a short time, the hardened magnets are by some makers plunged first into boiling water, then into cold every half minute for a day or two; others merely keep them in boiling water for a day. In either case the result is supposed to give a hundred-year-old magnet "while you wait." Curiously, a quicker and apparently as effective a method of artificially aging a magnet is accomplished by straddling it over a rapidly rotating copper disk. The magnet induces eddy currents in the disk, and these in turn react upon the magnet and by their demagnetizing force remove the unstable elements.

Particular qualities of steel have been found of value, the presence of tungsten being beneficial, while manganese is highly detrimental to permanency of magnetism.

To give stiffness to the movable coil and allow for the damping action of a closed circuit, and yet introduce the minimum weight, Weston made the rectangular frames of aluminium, all in one piece, with edges slightly turned up, thus giving a sort of channel section, and providing for retaining the wire in a substantial manner. For the voltmeters, two or three layers of No. 40 wire were wound on, while for the ammeters a single layer of somewhat larger size was found more convenient. The pivots had rectangular bases, and were stuck directly to the insulated wire by a very adhesive varnish. In consequence of the magnetic pull, steel hair springs would be out of place, hence those of phosphor bronze, such as are employed in non-magnetic watches, are substituted. A view of the coil and hair springs as located in place between the poles of the magnet is given in Fig. 95. A pointer made of aluminium tubing only 1/32 inch in outside diameter is attached to the upper pivot, and the outer

end flattened, or fitted with a suitable indicator, and moves over the scale.

The sensitiveness of these instruments quite approaches that of the laboratory pattern, and inside the case of the voltmeters about 100 ohms additional resistance for every volt to be measured is inserted. For instance, one reading to 15 volts has a total resistance of about 1,500 ohms, and for 150 volts 15,000 ohms. Two separate resistances are often comprised in the same instrument, with their respective binding posts, and thus make several instruments in one. For laboratory measurements this double scale range is of great convenience and economy. A voltmeter with scales of 0-5 and 0-100 is given in Fig. 96; the corner binding posts belong to the higher values, while the extra post on the left is used instead of the one on the corner when the 5-volt scale is desired. Such an instrument is seen to be of great convenience in battery work, using the main scale for the whole set, and the low scale for measuring individual cells. The danger is always present, however, of leaving the wires on the low-scale post, and accidentally connecting with the full voltage source. In such cases the pointer is usually bent out of shape, and the coil melted.

It will be noticed that the right-hand post is marked +; this definite polarity of permanent-magnet type of instrument is one of its most valuable properties, for without its aid the determination of the right connection between different dynamos or storage batteries would be precarious or even dangerous. If the negative pole is attached to the right-hand side, the pointer simply tries to go the wrong way. A push button is seen also at the right. By this device, the circuit is closed when desired, for taking a reading, but normally it is left open so as not unnecessarily to heat the resistance coil. The switchboard instruments, however, are supposed to be permanently connected, and the resistance coils are of large enough wire, and sufficiently well ventilated to insure no danger of errors in readings or of burning out of the wire.

The laboratory style of ammeter has two large binding posts, and in consequence of the stiffness of the wires likely to be used, convenience in removing or connecting, or changing instruments of different scales, is attained by having both posts on the same side, the positive one, by which the current must enter in order to move the needle forward, being still on the right hand. Up to 100 amperes capacity the lower resistance shunts are usually located within the case, but those for larger currents, especially of the switchboard type, have the shunts separate. In use, it is not necessary that these be close to the other part of the instrument, and this opportunity for separate locations is very convenient; for the large bars that conduct the main currents are usually located at the lower part of panels, while the indicating part of ammeters, along with the voltmeters, is desired at the top. The shunts, consisting of thin sheets of the proper alloy soldered into massive blocks of copper, are bolted across an opening in one bar, and ordinary lamp cord led from the two ends up to the little movable coil within the instrument case.

Fig. 97 shows a self-contained ammeter of Weston make, of 100 amperes capacity. In this picture and in Fig. 96, there is seen through the watchglass the means of adjusting the pointer to the zero mark; one end of the insulated lever is attached to the hair spring, the other to the circuit. A similar device is at the other pivot, and access to both is obtained by removing the back-board and then the cover.

As evidence of the small amount of energy necessary to operate an ammeter of this type, it may be stated that a thirtieth of a volt only is needed to drive the pointer entirely across the scale.

While the Weston type of direct current instruments is freely recognized as combining all possible good features, to the point of practical perfection, other forms have been made, many of them cheaper, and capable of filling many needs. That by Ayrton and Perry was once largely used, and previous to the production of the Weston, probably the best. It also employs a permanent magnet, but no moving wire. Fig. 98 shows the construction. A little oblong piece of soft iron is pivoted between the poles, the latter being somewhat adjustable in strength or position by means of the iron screws passing through them. When current flows through the coil of wire, the movable piece of iron takes a position along the resultant of the two magnetic fields.

The scale of the instrument is made somewhat short, and the divisions are not necessarily equal, and the movements of the pointer are sudden and jerky, rather than deliberate and dead-beat. This form of measuring instrument is, however, still made in large numbers, the familiar "battery-tester" being a good example.

By far the largest variety of cheap ammeters and voltmeters have no permanent magnets whatever, but depend upon the current to set up an electromagnetic field; these coils may be solenoids, into which light soft iron plungers, with pointers attached, may be more or less drawn; or the coil may be short, with one fixed and one movable piece of iron, whereby, in consequence of being similarly magnetized by the current, they will repel one another, and the pointer be moved; or a little piece of iron may turn so as more nearly to coincide with the axis of the coil.

Such instruments absorb at least ten times as much energy as those of the other sort, are just the opposite of dead-beat, and are greatly affected by the presence of other magnetic fields. Some appreciable energy is needed to coerce the iron into its initial magnetic state, and therefore, the first part of the scales are not useful, nor often calibrated; also, the extreme portion of scale is usually indefinite. Further, the residual qualities of even the softest iron are such that equal increments of current result in certain positions of the pointer, while the same values with diminishing currents leave the pointer in appreciably different positions. A more serious fault is that such instruments give no indication of the direction of current. In conjoint operation of dynamos, or with storage batteries, indication of the polarity of the circuit is of utmost importance.

The very fact that ammeters and voltmeters of this construction are not concerned in the direction of the current is suggestive of a peculiar field of usefulness for them, and that is for alternating currents. This is so important a subject as to require a special article, and Chapter XX will be devoted to it. In addition to instruments of the indicating type, some of the recording order will also be illustrated. It will be found that certain constructions are quite as well adapted to measuring direct currents, so that the next will really be a completion of this chapter.

AN UNDEVELOPED MONTANA COAL FIELD.

A 700-SQUARE-MILE AREA ADDED TO OUR FUEL RESOURCES.

A practically virgin coal field, comprising an area of about 750 square miles, lies on the divide between Musselshell and Yellowstone rivers, north northeast from Billings, Mont., according to Mr. L. H. Woolsey, one of the geologists of the United States Geological Survey, whose work last summer carried him into the Bull Mountain field. Except the old tunnels from which coal was extracted by the Northern Pacific Railroad men fifteen or twenty years ago, there is scarcely a prospect or country coal bank in the field, although the partial investigation made by the government geologists has discovered at least fourteen separate beds of coal that exceed 2 feet in thickness. It is probable that the total thickness of all the coal beds in the portion of the area studied will exceed 40 feet. One bed, locally known as the "Mammoth seam," is 15 feet thick in many places.

Roughly speaking, the field is bounded on the south by the southern edge of T. 5 N., on the west by Razor and Halfbreed creeks, and on the north by Musselshell River. The eastern portion of the field has not yet been studied, and its eastern limit is not even tentatively fixed. The Bull Mountains, rising 500 or 600 feet above the surrounding country, lie in the southwestern part of the field.

Analyses of samples of the coals from the Bull Mountain field, made in the fuel-testing laboratory of the United States Geological Survey, place them among the high grade sub-bituminous (black lignite) coals of the country. Thus the analysis of an air-dried sample of Mammoth coal collected in Sec. 30, T. 6 N., R. 27 E., gave the following results: Air-drying loss, 3 per cent; moisture, 14.90 per cent; volatile matter, 32.12 per cent; fixed carbon, 46.44 per cent; ash, 6.54 per cent; sulphur, 0.51 per cent; hydrogen, 5.28 per cent; carbon, 60.82 per cent; nitrogen, 0.92 per cent; oxygen, 25.93 per cent; calories, 5,797; British thermal units, 10,434. A similar analysis of a sample from the mine at Roundup shows these proportions of the constituents: Air-drying loss, 2.70 per cent; moisture, 10.27 per cent; volatile matter, 29.51 per cent; fixed carbon, 52.31 per cent; ash, 7.91 per cent; sulphur, 0.56 per cent; hydrogen, 5.29 per cent; carbon, 66.04 per cent; nitrogen, 0.90 per cent; oxygen, 19.30 per cent; calories, 6,300; British thermal units, 11,340. The sample from Roundup is much fresher than the sample of the Mammoth coal and this fact is shown by the analyses. It is believed that an analysis of a fresh sample of the Mammoth would compare much more favorably with the analysis of the Roundup coal.

When these analyses are compared with those of coals from Great Falls, Miles City, Red Lodge, Bear Creek, and the Bighorn basin, it is found that the Bull Mountain coals rank high. Few of these other coals have a greater and many have a somewhat less fuel value. The coals from all the beds are very similar in character and appearance. They are black, soft, and lustrous, give a blackish-brown streak, and slack readily on exposure.

The opening of this field is a present-day question. Recently, as a result of the coast extension of the Chicago, Milwaukee & St. Paul Railroad along Musselshell River, a shaft has been opened on one of the lower coals, two miles east of Roundup. The mine is now in operation, and coal is being removed for use on the new railroad and for local consumption. The full thickness of the bed at this point is said to be about 6 feet. The railroad extends along the northern border of the field and will not only make increasingly great demands for fuel for its own use, but will afford an outlet for shipping the coal to distant points; and to meet these demands and those arising from the growth of the towns in the vicinity of the railroads an extensive development of the Bull Mountain coals may be expected.

Field work in the Bull Mountain region is now being carried on by Messrs. R. W. Richards and M. A. Pishel, of the United States Geological Survey. A brief report on the area already covered will be published by the Survey during this summer as a part of Bulletin 341, and a detailed report on the whole region will be issued as soon as the survey is finished.

TRIPOLI NEAR SENECA, MO.

The deposits of light, porous, siliceous rock occurring so abundantly in the vicinity of Seneca, Mo., have for the last twenty years or more furnished material for the manufacture of an abrasive powder for general burnishing, polishing, and buffing and for use in various scouring soaps. The products closely resemble, both in use and appearance, similar articles made from tripoli and tripoli slates—infusorial deposits—and, though of entirely different origin, have been marketed under the commercial name tripoli stone or flour.

The most important use of this tripoli is for filter stones, which are turned out by the local mills in shapes and quantities to suit the manufacturers of filters of different kinds. These range in size from that of the ordinary house filter to that of a filter with a capacity of 400 gallons an hour, or batteries of such filters with any desired capacity. Ocular evidence proves that the tripoli filter effectively removes much of the matter mechanically suspended in the water that is passed through it, and bacteriological examination of the water before and after filtering is said to demonstrate its sterilizing efficiency. The stone also has a moderate sale for blotter blocks and scouring bricks.

The small or waste blocks from the quarry and the waste from the filter mills, after being thoroughly dried for two or three weeks, are crushed and ground into the product marketed as tripoli flour, which is sacked or barreled and shipped just as ordinary flour. This material is used as an abrasive powder and in scouring soaps, but thus far attempts to mold filter stones from tripoli flour to which a binder has been added have not been successful, as the binding agent has destroyed the porosity of the filter.

In a brief paper on these Seneca tripoli deposits, prepared by Messrs. C. E. Siebenthal and R. D. Mesler, geologists of the United States Geological Survey, and published by the Survey as an advance chapter from Bulletin No. 340 (Contributions to Economic Geology, 1907, Part I), it is suggested that the tripoli flour might possibly find use as the absorbent base in the manufacture of dynamite. Diatomaceous earth, formerly used for this purpose, has been superseded in recent years by a compound of sodium nitrate, wood pulp, marble dust, and various other substances, which has the advantage of entering into the combustion of the explosive, adding at a rough estimate, about 5 per cent to the force. Wood pulp now costs $30 per ton and its price is constantly increasing; diatomaceous earth costs $25 to $30 per ton; tripoli flour between $6 and $7 per ton. It is believed that the tripoli flour might be substituted for wood pulp, either wholly or in part, without greatly impairing the explosive value of the compound and at a possible saving of $3 or $4 per ton; and that, if experience should show serious impairment, it could be remedied by the addition of more nitro-glycerine and there would still be a notable

saving. As the two powder plants in the vicinity of Joplin produce about 30 tons of dynamite daily, the point would seem to be worthy of experimentation.

The report by Messrs. Siebenthal and Mesler discusses the geologic occurrence, character, and origin of the deposits and describes briefly the methods of quarrying and manufacture. It may be obtained without cost by applying to the Director of the Geological Survey at Washington, D. C.

CLOUDS, FOG, AND BLUE SKY.

THE VARIOUS FORMS OF WATER.

BY PROF. POYNTING

The air always contains water as a constituent, in the form of vapor or invisible gas, a gas which is, in fact, cold steam. This water vapor comes into the air by evaporation from the surface of the sea, and from any damp surface on land. The amount of vapor which the air can contain increases as the temperature rises; but for each temperature there is a limiting amount which is not exceeded. When the air holds this limiting amount it is said to be saturated. A cubic foot of air weighs about 550 grains. If it is at 32 deg. F. it can hold, or is saturated with, 2.1 grains of water vapor; at 60 deg. F. it is saturated with 5.7 grains; at 86 deg. F. it is saturated with 15 grains. Thus on a very hot summer day it can hold seven times as much water vapor as on a day when it is just freezing.

But, ordinarily, the air is not saturated at the surface. So puddles dry up after rain; that is, the air takes up the water in the form of vapor.

If air is saturated and is then lowered in temperature it cannot hold so much water vapor, and the excess is deposited as dew, hoar frost, mist, fog, or cloud, according to circumstances. Mist and fog may be regarded as cloud near the ground.

Cloud consists of minute water drops. The drops remain in the air because they are too small to fall quickly, the resistance of the air checking their fall. Really they do fall. Drops 1/1000 inch in diameter fall about ¾ inch per second; drops 1/10000 inch in diameter fall about 1/130 inch per second.

Cloud may be formed by the cooling of air by expansion. For instance, air near the surface of the ground may get warm, and may take up water vapor. It may get lighter than the surrounding air and rise up. As it rises, the pressure on it lessens, and so it expands. In expanding it cools, and if it cools so that it cannot continue to hold all the water vapor it acquired when warm, the excess is changed into liquid in the form of cloud. We may sometimes watch clouds form thus in summer at the beginning of a thunderstorm. We may see them form, too, at the top of a mountain when the air blows against the side and is forced to go uphill, expanding and cooling as it goes.

Mist is formed by the cooling of the air in contact with the cooled surface of the ground.

Cloud may be formed, too, by the mixture of two winds—one warm and vapor-laden, the other cold. The mixture may not be able to hold all the vapor, and cloud is formed.

Fog is perhaps formed by the air near the ground being very cold, so that it cannot hold much vapor. Overhead the air is perhaps warmer, and has more vapor in it. More vapor diffuses down than will saturate the cold air near the ground, and the excess is deposited as water drops or fog.

Cloud drops only form if there are particles of dust or other "foreign" particles present. A drop forms on each particle. By passing air through cotton wool we can filter out the dust particles, and in such air cloud will not form.

Town air is very full of dust particles—perhaps millions in a cubic inch. When a fog forms in a town the number of drops is very great, and each is very small. In country air the dust particles are much less in number—perhaps a few hundred or thousand in a cubic inch. The water formed in a country fog may be as much in quantity as in a town fog, but it is concentrated in fewer and larger drops. The fog is, therefore, not so thick. We may illustrate this by throwing a handful of grains of corn into the air, and then a handful of flour. Obviously the flour will make a thicker "cloud."

The small particles in the air play another part. It is to their presence in the upper air that we must ascribe the blue of the sky. We may illustrate their action by the similar action of small bodies floating on the surface of water when waves are traveling over that surface. If the waves are long from crest to crest, a small floating piece of wood, for instance, will ride smoothly up and down again. But if the waves are short, a crest has not time to lift the wood up, and the wood is partly submerged. The succeeding trough has not time to let the wood down, and it rises somewhat out of the water. That is, the wood bobs up and down in the water as each wave passes it. It therefore sends out waves of its own as it "pumps" up and down in the water. These waves derive their energy from the original waves, which go on a little weaker. Imagine a great many pieces of wood of such size, as compared with the waves, that this action takes place with each, and the waves will be seriously weakened.

The particles in the air above us are very minute. Sunlight consists of a great mixture of waves—long red waves, medium yellow and green waves, short blue waves. The particles ride, as it were, on the long red, yellow, and green waves, but the short blue waves shake them up and down and they send out blue waves on all sides—the blue of the sky. The blue waves in sunlight are thus weakened. Thus, at sunset the light passes through a great thickness of air, the blue light is scattered by the particles and much of it is lost before it reaches us. The red light survives, and so we have the red color of sunset.

NEW DISCOVERIES IN CONNECTION WITH "BROWN'S MOLECULAR MOTION."

I. The motion made visible to the naked eye.

Fine solid or liquid particles held in suspension or emulsion in a thin and mobile liquid (the oil globules of milk, for example) are in continual movement of an irregular vibratory character. This phenomenon is called Brown's molecular motion from its discoverer, the botanist Robert Brown. The motion is easily observed in the milky sap of the spurge (*Euphorbia*). If a drop of the sap of the well-known greenhouse plant *Euphorbia splendens* is placed on a microscope slide under a cover glass and magnified from 300 to 1,000 diameters, the milky liquid is resolved into a clear fluid containing in suspension exceedingly fine particles of resin and caoutchouc, which exhibit Brown's molecular motion very beautifully. Hitherto, so far as I know, this motion has been observed only under the microscope but it can be made visible to the naked eye. For this purpose it is necessary to illuminate the liquid by direct sunlight. The slide bearing the drop of sap should be held nearly vertical, with the sun's rays falling obliquely upon it, and viewed by transmitted light. When the most favorable position is found the motion of the microscopic resinous particles is strikingly revealed by a peculiar and lively dancing and shimmering of the brilliant interference spectra which they produce. Another very good object is India ink, rubbed up with water.

It appears surprising that the extremely fine particles of spurge sap, which are near the limit of visibility under the microscope, can be seen at all with the naked eye. The obvious explanation is that the luminous rings and brushes caused by diffraction of the strong sunlight produce comparatively large images on the retina, as they do in observation with the ultra microscope.

II. Brown's molecular motion in gases, as observed with an ordinary microscope.

Ehrenhaft has recently shown that a phenomenon similar to Brown's molecular motion can be detected with the ultra microscope in condensing vapors of silver, gold, platinum, and other metals. The particles of metal which exhibit this phenomenon are, according to Ehrenhaft, of ultra-microscopic dimensions, but I find that the motion can be detected in many gases with an ordinary microscope of low power, with the usual method of illumination. My method is as follows:

A glass ring about ½ inch in diameter and ⅛ to ¼ inch wide is cemented on a microscope slide. On the back of the slide, exactly opposite the center of the ring, a circle 1/24 to ⅛ inch in diameter is blackened with India ink. A microscope of a power of 50 or 75 diameters is focused on the center of this black spot. The little cup formed by the slide and the glass ring is then filled with tobacco smoke and quickly covered with a cover glass. In very oblique illumination with direct sunlight, from above, the particles of smoke appear as countless white dots on a dark background, and the dots dance and quiver like the resinous particles of spurge sap. The stronger the light the more conspicuous is the phenomenon, owing to the increased apparent size of the diffraction rings. The best illumination is direct sunlight or the electric arc, but the motion is clearly visible in the light of an Auer burner, a powerful incandescent electric bulb, and even in diffused daylight on a cloudy day. Clouds of sal ammoniac and phosphoric oxide show the movement as well as smoke.

It should be noted that the movements of smoke particles were observed by Bodaszewsky, to whom they suggested "an approximately correct picture of the hypothetical motions of molecules according to the kinetic theory of gases." Smoluchowski recently arrived at the theoretical conclusion that a molecular motion similar to Brown's motion must occur in gases —a conclusion which has been verified by Ehrenhaft's experiments and mine.—Prof. Hans Molisch in Die Umschau.

THE FOUNDING OF THE ROYAL INSTITUTION.*

A HUNDRED years ago last October, there happened one of those events to which the term epoch-making may, without cavil or question, be fittingly applied.

Let me attempt to recall the circumstances which led up to that cardinal discovery of which to-night we celebrate the centenary. These are connected partly with the Royal Institution itself and partly with the state of science in the early years of the nineteenth century.

In the year 1807 the institution was entering upon the eighth year of its existence. The Royal Institution grew out of a proposal to deal with the question of the unemployed, namely, by forming in London by private subscription an establishment for feeding the poor and giving them useful employment, and also for furnishing food at a cheap rate to others who may stand in need of such assistance, connected with an institution for introducing and bringing forward into general use new inventions and improvements, particularly such as relate to the management of heat and the saving of fuel, and to various other mechanical contrivances by which domestic comfort and economy may be promoted. Such was the original prospectus, but, like many other prospectuses, it failed to equal the promise its proprietors held out.

Eventually the promoters decided, on the initiation of Count Rumford, that the Associated Institution would, as they expressed it, be "too conspicuous and too interesting and important to be made an appendix to any other existing establishment," and therefore it ought to stand alone on its own proper basis. Accordingly, the problem of the unemployed still remains, while the new institution took the form of converting Mr. Melish's house in Albemarle Street into a place where, by regular courses of philosophical lectures and experiments, the applications of the new discoveries in science to the improvement of the arts and manufactures might be taught, to facilitate the means of procuring the comforts and conveniences of life.

HOW WATER MUST BE LABELED.

UNDER a ruling promulgated May 23 by Secretary of Agriculture Wilson hereafter manufacturers and mineral water dealers are to label their product as artificial, imitation, or natural. The new regulations will provide that no water shall be labeled as a natural water unless it shall be the same as its source, without additions or abstractions of any substance or substances. The regulations also provide that no water shall be labeled as "medicinal water" unless it contains one or more constituents in sufficient amounts to have a therapeutic effect, and no water is to be named after a single constituent unless it contains such constituent in sufficient amounts to have a therapeutic effect when a reasonable amount of the water is consumed.

Hereafter it will also be considered a violation of the pure food law if the label on a bottle of manufactured water bears any design or device, such as pictures of springs or fountains, which might lead the consumer to believe that the water was natural. Manufactured water may be named after a natural water in case the word "imitation" or "artificial" is also used.

* A lecture delivered at the Royal Institution of Great Britain.

WHY ARE EGGS COLORED?

THE CURIOUS PHENOMENA OF EGGSHELL PIGMENTATION.

BY W. P. PYCRAFT.

HE would be a bold man who would attempt to describe all the varied hues and patterns which birds' eggs display; and his labor would be lost in the interminable and repellent descriptions in which such an attempt to realize the impossible would involve him. But two points must necessarily strike anyone confronted with a large and representative collection of eggs. First, that the colors displayed bore no sort of relation to those of the birds which laid them; and, secondly, that there was little about these eggs that would enable him to decide the particular species or even genus to which such and such an egg belonged, rare cases only excepted. The markings of these shells range through minute frecklings, such as are met with in some game-birds, to blotches and smears, and irregular lines and streaks, which suggest hieroglyphics of some sort, as in the eggs of buntings, and the jacanas among the plovers; while many eggs are what is called "double-spotted," on account of the fact that many of the spots are but faintly indicated, and evidently deposited in a deeper layer of the shell. In some eggs, as in those of certain petrels, the pigment is almost and sometimes entirely confined to a zone around the larger end. But, perhaps, the most striking fact about this coloration is the lack of uniformity which prevails among even closely-allied species, species which in plumage bear an exceedingly close resemblance, while birds in no way related may lay very similar eggs. Not only, indeed, do nearly-allied species lay eggs of widely different coloration, but instances are numerous where differences no less striking obtain between eggs of the same species, of which the murre affords one of the most striking and familiar instances; and much the same is true of the shape of eggs. Nevertheless, there are not wanting ornithologists who, in the face of these facts, employ coloration, or the lack of it, as a factor in classification.

Contradictory though it may seem, it is yet true, however, that in broad outline we may distinguish the eggs of the larger groups, though, as might be expected, exceptions are frequent. Thus, for example, the eggs of the tinamous are recognizable at a glance from their extraordinary burnished appearance, resembling highly-glazed earthenware or polished metal. Among the petrels such eggs as are colored have the pigment deposited in the form of a cap or zone around the large end, though this peculiar distinction is not confined to the eggs of this group. Of the gannet tribe—including pelicans, frigate, and tropic birds—the tropic birds only lay richly-colored eggs, those of the remaining families being thickly incrusted with a white, chalky deposit, concealing—as in the cormorants and gannets—a shell of a beautiful blue color. The anserine birds, without exception, lay whole-colored eggs; so also do the stork tribe, whose eggs are generally blue or green in color, though, in some cases, as in the ibises and flamingoes, they are white and chalk-covered.

The eggs of the birds of prey are either wholly white, or have a ground color of white, bluish white or buff, spotted and blotched with various shades of red and purplish. Frequently the ground color is covered by spots, which are so thickly clustered as to give the egg an almost uniform rust, sienna red, or inky purple hue. Thus the eggs of birds of this group are often of rare beauty. While the game-birds, as a rule, lay whole-colored eggs—generally cream or buff-colored—there are some whose eggs are spotted and some double-spotted.

C. Reid, Wishaw, N. B. Copyright.

YOUNG LARKS.

The grouse, snow-cocks, and red-legged partridges lay spotted eggs, as also do the quails. In these last a wonderful range of variation is met with, as for example in the Australian swamp quail, no two clutches of which are alike, some eggs being white, others cream-colored, while others yet again are sparingly or thickly freckled and blotched with gray, rufous, or brown. In the chuckar partridge again the color shows a wonderful range of variation, which is apparently correlative with the geographical range of the species. The eggs of the crane and rails are always more or less spotted, excepting only Sharpe's rail Sarothrura (*insularis*), which lays a white egg. While in the rails the spots are small and usually of various shades of Indian red on a cream ground, in the cranes the coloration is stronger, forming large spots and blotches of various shades of brown and purple on a dark, occasionally light, ground.

In the plover tribe, and herein we include the gulls, auks, and murres, the eggs are all spotted with various shades of brown and black on a groundwork ranging in hue from white, cream, brown, and blue and green. The jacanas are exceptions to the rule. One species—the pheasant-tailed jacana—lays a white egg, while the remainder have the shell covered with inextricably-twisted lines, forming a sort of tangled meshwork. But in the matter of variability none can compare with the eggs of the murres; no less than thirty well-marked varieties are exhibited of these eggs in a special case at the British Museum of Natural History. The great range in pigmentation is really wonderful, but still more wonderful is the variability of the size and distribution and shape of the markings, which no words can adequately describe. The significance of such extreme variability is far from apparent, but it has been suggested that, inasmuch as each murre keeps throughout its life to one particular style of color and marking, this individuality may be the outcome of natural selection, the end gained thereby being to enable each bird in the colony to recognize its eggs.

We may bring this brief survey to a close with a few comments on the eggs of that great assemblage of forms grouped by systematists under the collective term of "Pico-passeres," which includes the cuckoos, parrots, hornbills, bee-eaters, rollers, humming-birds, nightjars, owls, barbets, puff birds, woodpeckers, and toucans, and the "passerine" or perching birds. Among the non-passerine species of this vast host white eggs are the rule, but among the passeres they are the exception. But though in their coloration the eggs of this group present great variety, and often great beauty, it is impossible, except in some very rare cases, to associate any particular style of coloration with any particular species, or even family. A word as to the size of "clutches" and we have done. Since among birds the eggs must be incubated by the warmth of the parents' body, it is obvious that no more eggs can be hatched that can be covered by the sitter. But even with this limitation there is a considerable range in the number produced by different species. The ostrich tribe, the game-birds, rails, and anseres represent the most prolific, the ostrich successfully hatching out as many as thirty eggs at a time—the produce of four or five females—the partridge twenty-five, the quail twelve, the mallard twelve, the teal fifteen; while at the other extreme we have the murres, which lay but one egg, the pigeons two, or the gulls and plovers, which never exceed four. Between these numbers and the death-rate which is levied upon the nestlings there is a very intimate relation, which, however, demands a chapter to itself.

T. A. Metcalfe.

KESTREL.

PIED FLYCATCHER, COCK.

Copyright.

PIED FLYCATCHER, HEN.

A CAPTURE OF FULL-GROWN GORILLAS.

By DR. TH. ZELL.

CAPT. DOMINIK, of the German army, has performed a feat which was regarded as impossible by taking alive and unharmed three gorillas, of which two were fully grown and the third nearly so.

There is no authentic record of any other capture of an adult gorilla. The ancient Greeks, Romans, Egyptians and Carthaginians were adepts in the taming and training of wild animals, including the crocodile and the African elephant—for the war elephants of the Carthaginians were presumably of the African species. The African elephant has never been tamed in modern times and the first trained crocodiles were exhibited by a French trainer a few years ago. There are some passages in ancient writings that may be interpreted as referring to the capture of gorillas but the indications are by no means certain and it must be remembered that the Greeks and Romans, and even the Egyptians, knew only by hearsay of the gorilla.

which is confined to the west coast of Africa, near the equator.

The difficulty of capturing these gigantic apes is due to their great strength; to the fact that they lead a nomadic life in almost inaccessible forests and morasses, infested with fevers and surrounded by hostile savages, and, above all, to their skill in climbing trees, which makes it impossible to take them in pitfalls and starve them until they can be lassoed and bound, which is the approved procedure in the case of lions, elephants, rhinoceroses, crocodiles, and other powerful animals.

G. A. Booth. Copyright.

SANDWICH TERNS ON THEIR NESTS.

A similar difficulty exists in the case of the orang outang but this Asiatic ape is neither so strong nor so savage as his big African cousin. The Dyaks of Borneo capture full-grown orang outangs in the following manner: The animal is surrounded and forced to take refuge in a large tree which stands alone or in the midst of small trees and bushes. These are cleared away to a distance of a hundred feet or more in every direction and the ape is prevented from escaping across the clearing by a circle of fires and an armed guard. A day or two later, when the treed orang outang has become very hungry and thirsty, a dish of sugar cane sap, mixed with a narcotic drug, is placed on one of the lower branches. The hunters conceal themselves and the orang outang drinks the sweet liquor which, if it is of the right strength and quantity, soon makes him so drunk that he can do little more than hold on to the branches. (If the dose is too powerful he may fall to the ground and break his leg or even his head—an accident which would materially diminish his value.) The tree is now felled and as the stupefied ape, still clinging to the branches, comes down with it, an infusion of red pepper is dashed into his eyes and he is lassoed and dragged out to a wicker cage, which is adroitly turned over him. A copious shower bath sobers him and washes the pepper out of his eyes and in twenty-four hours he has recovered his normal health. He is then fed with fruit but his subsequent diet consists chiefly of boiled rice.

This procedure, which is thus described by an eye witness, Capt. Storm, is hardly applicable to gorillas, and it is not difficult to understand why it has usually been found impossible to induce the natives of Africa to attempt the capture of an adult gorilla.

Our first certain knowledge of the existence of the gorilla was obtained, only fifty years ago, by the American missionary Wilson. Further information was subsequently given by Savage, Du Chaillu, and Reade, but their descriptions differed in many respects, and especially in regard to the strength and ferocity of the great ape. Koppenfels, the first European who unquestionably killed an adult gorilla, takes a middle position, asserting that the gorilla usually flees from man but that he is sometimes goaded to attack, and then becomes a formidable adversary.

Gorillas were not certainly known to exist north of the equator until 1900, when Paschen shot in Kamerun a gigantic specimen, which was exhibited in Berlin in the following year.

Koppenfels agrees with all the earlier observers in stating that gorillas, unlike chimpanzees, are never seen in herds, but always live singly or in families, each of which comprises an adult male and one or more females, with their young. Dominik asserts, however, that the gorillas of Kamerun live in herds.

These contradictory statements are not to be wondered at. The Greeks and Romans asserted that the lion never lives in herds, and this is true of the Barbary lion. Hence the modern discovery that lions hunt in troops on the steppes of East Africa was greeted with surprise and incredulity. Schillings, in his well-known book, "With Flashlight and Rifle," speaks of putting to flight a troop of fourteen lions. The difference in habit is explained by the difference in local conditions. In a mountainous country a lion can stalk and capture his prey unaided, but a single lion would starve on the open steppe.

South of the equator the gorilla has but one formidable enemy, the leopard, and he can defeat even this one in single combat. There are no lions south of the equator.

According to Capt. Dominik the Kamerun gorilla country is also free from lions, but it is infested with crocodiles and inhabited by elephants, buffaloes, and other large herbivora, which appear to make it necessary for the gorillas to herd together.

Capt. Dominik, who personally communicated to the writer the following account of the gorilla hunt, agrees with other observers that the gorilla, though an excellent climber, lives chiefly on the ground and may be classed as a rock dweller.

In Kamerun, as in more southerly regions, the natives have an unbounded respect for the great ape, and show no desire to molest him. The belief that gorillas carry off women is as general here as elsewhere and the behavior of other simians in zoological gardens gives some plausibility to the tradition. Furthermore, the gorilla shot by Paschen had killed three of Paschen's native assistants, by crushing their chests, before he was laid low, and another gorilla had recently torn off and devoured a man's leg. Hence, when Dominik had located a large troop of gorillas, he found the task of collecting hunters exceedingly difficult. Another man would have failed, but Dominik, in his fourteen years of service in the colony, had made himself so beloved by both blacks and whites that they were willing to go through fire and water for him. The natives regarded him as a medicine man, or wizard, of great power because he had survived many bloody battles and severe wounds and because he had caught and tamed young elephants, buffaloes, and lions.

He succeeded, therefore, in engaging nearly a thousand blacks. By dint of shooting, shouting, and beating on hollow trees the gorillas were driven in panic from the rocky defiles of Mt. Launde to a forest glade where they were surrounded and penned in with strong nets. The drive occupied two days. At night, fires were lighted around the inclosure and any gorilla that attempted flight was driven back by shouting and hurling fire brands. In the evening of the second day the hungry apes made a combined effort to scale the nets and escape. Two were shot and the others were driven back. It was a moonlight night and Dominik determined to attempt the capture, with the aid of twenty picked men and a number of dogs. Several gorillas were shot, two big males escaped, but three nearly full grown apes were captured by throwing nets over them and holding them down with long forked poles, while they were fighting with the fierce native dogs.

The gorilla, like the lion, tiger, and elephant, usually flees from a crowd of men shouting and firing guns, but when wounded or brought to bay he quickly turns, like a bear, on his hunters. At such a time he presents a terrifying appearance. His open mouth reveals his great canine teeth and his big right hand is raised to strike, while his left arm is used as a crutch.

The youngest of the three captured gorillas was sent to the aquarium in Berlin where he lived only a few days, like most of his predecessors. The two adult gorillas fared no better in Hagenbeck's park at Hamburg, where one of them lived thirteen, the other seventeen days. Both Hagenbeck and Dominik attribute the death of the gorillas to melancholia caused by their captivity. They kept to themselves and refused to take part in the frolics of the other apes. Capt. Dominik is likely to be the last, as he is the first, man to capture an adult gorilla, for the favorable combination of circumstances which he enjoyed is seldom met with.—Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from Die Gartenlaube.

O. G. Pike. Copyright.

TAWNY OWL.

T. A. Metcalfe. Copyright.

LONG-EARED OWL.

GREEK VASES: THEIR SCIENTIFIC STUDY.*

By Prof. JAMES RIGNALL WHEELER.

THE scientific study of vases is comparatively new, in spite of the fact that the older museums of Europe have for a long time possessed large collections. The subject is a difficult one, since it includes products which differ greatly in style, and the reciprocal influence of the various styles is still in many cases imperfectly understood. Until rather recently the best known classes of these vases, both black and red-figured, were indiscriminately called Etruscan, and even to-day one sometimes hears this term popularly applied to them. We now know, however, that comparatively few of them are really Etruscan, and these of inferior quality; although found in Italy, they are for the most part Greek and to a large extent Athenian. It is the excavations of recent years, like those on the Athenian Acropolis, which have made a scientific study of this branch of Greek archæology possible. So long as the vases were known merely in museums, and the records of their discovery were either wanting entirely or were very defective, no progress could be made. Now archæologists are able to work in the light, since many vases found actually on Greek soil, and in many different localities, have made the scientific classification of museum specimens possible.

Apart from the importance of vases in furnishing chronological clews to the excavator, and apart from the actual beauty of the best specimens, they are of uncommon interest as throwing light, not only upon the major art of painting among the Greeks, of which we know little, but also upon mythology. This comes from the fact that it was the habit of the vase decorators to choose the subjects that they represented from the rich store of Greek legend. The greater painters chose their subjects from the same source, and so it is to the vases that we must chiefly look in trying to form some conception of the work of these painters, which we know of otherwise only through literary tradition. Certain Attic vases, for example, dating from about the middle of the fifth century B. C., apparently throw much light upon the school of the great artist Polygnotus. The relation of vase paintings to the Greek epic, the store-

* Abstracted from a lecture on Archæology, delivered at Columbia University in the series on Science, Philosophy and Art.

house of legend, is analogous. Countless scenes taken from the popular mythology are represented on the vases. Sometimes they are quite in accord with literary tradition, again they reveal interesting variants from this tradition, and not infrequently a vase may show some form of a legend not otherwise known. The vase painter, however, did not work solely in the atmosphere of mythological tradition; he often chose subjects from everyday life. The school-room, the palestra, the symposium, the boat-race, the ceremonies of marriage and death, and other everyday events furnish him material; there is in Boston an interesting *amphora* upon which a scene representing a woman being measured for a pair of shoes is painted. Taken all in all, there is perhaps no department of Greek archæology which illustrates more plainly than vase painting does the light such study may throw upon a past civilization. The fact that it was a comparatively humble occupation, carried on by handicraftsmen, only makes it seem to draw us the nearer to the popular tradition and life.

NERVE AS A MASTER OF MUSCLE.*

THE TIES BETWEEN MUSCULAR AND NERVOUS ACTIVITY.

BY PROF. C. S. SHERRINGTON, F.R.S.

We have on the table before us two muscles. The animal was dead when they were taken from it a short while ago. But the animal was, as we are ourselves, an assemblage of organs, and many of these organs go on living for a certain time after the animal, as an animal, is dead. Hence these muscles, carefully removed, are still alive. We notice a marked difference between their behavior now. To understand the behavior of organisms we have to think of them as processes rather than as structures. An animal is something happening. The function of muscles is to contract. Of the two muscles now before us, one still goes on contracting, although quite isolated from the body of which it formed a part; but the other does not contract, although that is its function in the body. The muscle which still goes on contracting is the heart; the other is a muscle like the biceps of our own arm. We might think that, as it rests there motionless, it is not alive. It is, however, fully alive. We can satisfy ourselves of that. If I apply to it a faint electric current, it answers by exhibiting its functional activity—it contracts. Yet it does not contract of itself, nor will it, however long we may preserve it; it will die without of itself even contracting once. What is the significance of this difference between the two?

The secret of this difference is largely an affair of the nervous system. The tie between muscular activity and nervous activity is always close; but it is very different in different muscles. The nervous system has been called with a picturesque truth, the master-system of the body. It controls the action of organs; it controls, quite especially, the activity of the muscles. This heart which we see beating here receives nerves. One of those nerves when stimulated will cause it to contract less, the other to contract more. The contraction of the heart is its "beat." The vagus nerve slows the beating, the other nerve quickens the beating.

The heart is a tubular muscle; it drives blood through itself. When it contracts it squeezes the blood from it into the arteries, and so the blood flows to feed all the myriads of minute lives—cells—composing the whole complex living animal. The lives of these myriad minute entities all depend on their supply of blood, and therefore the life of the whole creature depends on the contraction of the heart. At each beat the heart by squeezing the blood out of its arterial end maintains the flow of blood, and this flow resulting from its own contraction refills it, because the blood returns to it by the veins.

This beating is all which the heart has to do. Whatever happens it must continue to do this, or the creature perishes. Life-long, night and day, winter and summer, it must do this. Whatever act the creature may be accomplishing, sitting, walking, feeding, sleeping, catching its prey, or escaping its enemies, this beating must go on, in the frog about ten times a minute, in ourselves about seventy times a minute. The task is monotony itself. How admirably is the heart muscle adapted to fulfill it!

Self-adjustment to meet the environmental conditions differentiates animate from inanimate nature. As characteristic as this self-adjustment itself is its constant trend toward what has sometimes been termed "purpose." Animate objects are observed to adjust themselves to their own advantage, that is, so as to prolong their individual existence or that of their species. The more we know of them the more complete appears to us this trend in their reactions. The living organism advantageously adapts itself to its surroundings; and every part of a living organism exhibits this power. The heart-muscle reveals it clearly. It must not tire, and in normal circumstances the healthy heart, unlike other muscles, shows no fatigue. Its beat must always be strong enough to press its contents over into the artery against considerable resistance which opposes it. A heart-beat which did not expel the blood would be useless, worse than useless, wasteful, because it would be energy spent in vain. Its task can be roughly likened to that of a man with a bucket who has to keep lifting water from a tank at his feet to pour it over a wall of certain height before him. If he lift the bucket much above the wall he expends more energy than he need do; if he lift it less than the wall's height his work fails altogether. If he still, when the bucket is emptied, keep it above the wall's height, his work stops, although his effort does not.

The heart, whether its stimulus be weak or strong, beats always with sufficient power; it thus avoids the useless labor of a beat too weak to fulfill the office of a beat. If the heart were to give too prolonged contraction it would defeat its own purpose; after its beat, which empties it of blood, it must relax to refill for the next beat; to keep contracted would be for its purpose as harmful as to cease from beating; it would stop the blood instead of pumping it onward. In harmony with this, we find a prolonged stimulus to the heart does not keep the heart contracted; after the heart has replied to the stimulus by a beat it exhibits a refractory phase, during which it pays no attention to the further stimulation, and relaxes; and only after it has fully relaxed does it again pay attention to the stimulus and contract, that is to say, beat again. In short, it replies rhythmically to a continued stimulus which would keep the other muscle continuously contracted.

That the heart should go on beating after removal from the body does not seem greatly surprising, because it is still then alive. The wonder lies rather in its continuing to live so long when thus removed; that granted, it seems natural that it should do what it has done previously all its life.

But this other muscle, which likewise continues to live when removed from the body; it, though it *can* contract, does not. That seems—at least at first sight—the more remarkable. Why does this muscle stop? So long as it was part of the living creature it showed contraction over and over again. We must turn to the nervous system for our answer.

In the first place let us note that an animal, unlike that other great example of life, a plant, cannot nourish itself from naked earth and air alone. The plant strikes down roots and throws up leaves, and draws through these material and energy with which it can replenish its own substance and activities. Where it as a seed fell, there its foster-mother Earth gives it the food it wants. Not so the animal. It must have subtler and rarer stuffs, or die. The material it needs is not spread so broadcast. It, to replenish itself, must have more special material; it must have for food material that is living, or has lived. To obtain this it has to range about. It has to hunt for it; and it itself is hunted by other animals following the same quest. Therefore its very existence involves locomotion. It must find food and seize it, and must itself escape being found and seized. It is both hunter and hunted. Moreover, in a vast number of cases it has to seek its kind to propagate its species. The movement necessary in this great game of life is million-sided—subtle beyond words—and most animal lives are spent in nothing else. Existence for the individual and the race depends upon success in it. Man plays it also—let us hope that sometimes he plays something else as well. In all cases the chief instruments of the game are the skeletal muscles, those muscles of which the biceps of our arm may stand as type. An old philosophic adage has it that all which mankind can effect is to move things. The dictum illustrates how supremely chief an executant of man's activity his muscles are. All the things which man can move are moved in the first instance by that prime thing which he can move, his body; and for this his main agents are his skeletal muscles. These execute his movements, but in doing so are but the instruments of his nervous system. Therefore it is in reality the nervous system which is the player of the game; and it is because it is really the nervous system which is the player of the game that man is the most successful creature on earth's surface at the present epoch, for his is the nervous system which, on the whole, is the most developed, much best adapted to dominate the environment.

To understand a little how the nervous system compasses this end we may turn to examine its performance in some of its simpler governing of the muscles. Its main office is to react to changes in the environment. The animal body is provided with a number of organs specially attuned to react to changes in the environment. These changes, in so far as they excite these organs, are termed stimuli. Thus, it has organs stimulated by the radiant energy of light and heat, others by chemical particles drifting from odorous objects, others mechanically by objects touching the skin, and so on. These organs specially adapted to environment stimuli, are called *receptors*. Attached to them are nerves. Through these the excitement set up in the receptor by a stimulus spreads to the general nervous system. Arrived there, two kinds of effect ensue from it—one, a change in nerve-cells innervating muscles and glands, the other, a change in consciousness on the basis of sensation. These two effects are separable. The former, or "reflex" reaction, is not necessarily accompanied by any manifestation of the latter, though it may be so, and very often is so. We will confine ourselves to the former, or purely reflex effect, and to its operation on muscle.

The endowment with receptor organs is not equally rich in all parts of the body. It is the external surface of the animal which, as we might expect, has them in richest profusion; and the receptors of the external surface are likewise those most developed, specialized, and sensitive. This also we might expect; for it is the external surface that for countless ages has felt the influences of the illimitable outside world playing on it. Through refinement of the receptors of its outer surface, the animal has been rendered sensitive in many cases to stimuli delivered even by the remotest stars.

It is a feature of receptors generally that they react most to their agent when the intensity of that agent changes, and the more so the more abrupt the change. It is, therefore, changes in the outside world that operate especially as stimuli, though, of course, only changes which have relation to the animal in question. If we regard the mutual relation between the animal and the world at any moment as an equilibrium, then we can say that any change in the world which changes that relation disturbs the equilibrium.

Take the instance of a child asleep. A thousand agencies of the external world are playing upon it. Upon its skin, for instance, there is the pressure of the child's own weight against the receptors, and there is the pressure of the clothes which cover it; yet it lies restful. Suppose we touch its foot. That is a change in the external world in relation to the child. The familiar fact is that the foot is drawn up out of harm's way, as it were. The change has acted upon the child as a stimulus to some receptors of the skin. It may be quite unconscious of the touch, for its sleep may be deep. Yet the reflex action has occurred, and has done the appropriate thing. A candle may be brought into the room and its light reach the face of the child. That is a change in the outside world in relation to the child. The familiar fact is that the child's head turns from the light. It *sees* no light, but reflex action averts its face. Or, turning to other forms of life, take a fish quiet in its aquarium. A worm is dropped into the water, and the disturbance of the water reaches the surface of the fish. The fish turns and seizes the morsel. Such a reaction on the part of such a creature is probably wholly reflex.

The point for us here is, that the changes in the outside world which act as stimuli bring about appropriate readjustments of the body to the external world, and that in doing so the instruments of readjustment are the skeletal muscles, worked by the nervous system. The child's heart goes on beating, whether the child's foot lies quiet, or is moved, whether its face lies this way or lies that; the fish's heart whether the animal's skin was stimulated by fresh commotion in the water, or was not. But with the skeletal muscles it was different. Flexor muscles of the leg, that were relaxed, are by the touch to the foot thrown into ac-

* A discourse delivered at the Royal Institution.

tion; muscles which lay relaxed were, when the light came, caused to contract, turning the head away. Muscles of the fish that were inactive were thrown into activity by the new commotion in the water. It is these skeletal muscles, therefore, that the daily thousand changes of the external world so repeatedly and constantly affect in this way or that, and in reflex action it is always the receptors and the nervous system which impel them to react; and the result is to re-adjust advantageously to the animal its relation to the altering external world. Hence these muscles are called the muscles of *external relation*. So prominent are these muscles in the everyday work of life that they are *the* muscles of ordinary parlance. The man in the street is hardly aware that he has in his body any other muscles. These muscles are, through the nervous system, driven by the external world. The world outside drives them by acting on the receptors. It is not surprising, therefore, that this little muscle, removed from the body, and therefore separated from the nervous system and all its receptors, remains, although still living and able to contract, as functionally inactive—for contraction is its function, and it does not contract—as if it were already dead.

Now this muscle, when in the body, was the servant of a thousand masters. It had to contribute to a thousand acts. In a certain sense, it, like the heart, had to do for them all but one thing, inasmuch as it had to pull the limb in one certain direction; and yet its task is a very varied one. It has to pull the limb sometimes far, sometimes very slightly, or through all intermediate grades. It has to pull it strongly against great resistance, or weakly, and with all intermediate grades of intensity. We may suppose that in the course of evolution it has become adapted to this scope of purpose.

And indeed we find it so. Unlike the heart muscle, this muscle when a strong stimulus is applied contracts strongly, when a weak stimulus, weakly; under a long stimulus it contracts long, under a brief, briefly. The nervous system, in making use of this muscle, wants of it just such varied action as this—now weak, now strong, now brief, now long, as may be suited to the act required. The little organ is admirably adapted to be the animal's instrument in the world in which it is placed. This muscle has its place in the economy of nature, and into it it fits as a key into the lock for which it has been made. Man's naïve view, until somewhat recently, was that the earth and the universe were made to fit him. Was the universe made to suit this little muscle or was this little muscle made to suit the universe? The problem concerning this muscle and that concerning man are, in so far, the same. Surely our answer is that the muscle and the rest of the universe fit each other because they have grown up together—because they are part of one great whole; they fit just as a lock and key fit because they compose one thing, and it is pointless to ask whether the lock was made to fit the key or the key the lock.

The office of the nervous system is to co-ordinate the activities of the various organs of the body, so that by harmonious arrangement the power and delicacy of the animal's mechanism may be obtained to the full. When reflex action withdraws the foot of a sleeping child, it is not merely one such muscle as this which moves the limb, but many. The limb has many muscles, and even in such a simple act many and many of them are employed.

That the act occurs during sleep shows that consciousness is not its necessary adjunct. A similar act can be similarly evoked in an animal when the brain—the seat of consciousness—has been removed. The brain can be removed under deep narcosis of chloroform without any pain or feeling whatsoever. After that removal the animal is no longer a sentient or conscious thing at all. Then we can study in it the power of reflex action sundered from conscient and sentient life altogether. Then it is that opportunity is given for further reverent analysis of those wonderful and subtle workings of the nervous system which in ourselves are so difficult to unravel for the very reason that their working goes on without appeal to, and often beyond access of, the conscious self.

When analyzing the muscular action of even so simple a reflex act as that of drawing up the foot, a fact which early meets the observer is that the nervous system treats whole *groups* of muscles as single mechanisms. In lifting the limb it employs together muscles, not only of one joint of the limb, but of all the joints—knee, hip, ankle, etc. It deals with all these muscles as if they were but one single machine. If the movement is forcible, it throws them all into strong contraction; if weak, into weak. In the grading of the reflex action its influence is graded in all these muscles alike. So also the contraction in all of them is timed to begin together, to culminate together, and to desist together. Further, although the movement of this lifting of the limb is mainly flexion at its joints, the reflex accomplishes along with that some internal rotation of the hip and some abduction of the thigh. Why it should do so we shall see presently. Suffice us for the present that, besides the flexor muscles, the nervous system brings into play, at the same time and harmoniously with those, two other great groups of muscles, the internal rotators and the abductors. So perfect is its skill in using the muscles as its instruments that it can deal harmoniously and simultaneously with all these individually complex groups of motor organs as though they were but one.

Were we to attempt to produce this movement in the limb experimentally without employing its nervous system, we should have to apply I know not how many stimuli simultaneously to more than half the muscles of the limb. Not only that, but we should have to grade the stimulation of each of these most accurately to a particular strength. We should also have to arrange that, not only did each stimulus develop its full strength with the right speed, but that each should maintain it for the appropriate time and desist at the right speed and moment, and with proportioned intensity. Moreover, in the real reflex act the contraction of this or that muscle is now stressed, now subdued, with a delicacy and accuracy baffling all experimental imitation. The co-ordination in even the simple reflex we are considering may be likened to that exhibited by a vast assemblage of instruments in very perfect orchestration directed by a supremely capable conductor.

But it is more subtle and delicate than that, even in the simple reflex we are considering. The co-ordination goes much farther than we have yet assumed. The musculature of the limb is an instance of that kind of musculature which obtains where parts are adapted to move, not in one direction only or one way only, but in many. The limb has to do many different things. It has, according to circumstances, to bend or to straighten, to turn inward at one time, at another to turn outward, to move this finger or move that. Its musculature is therefore split up into many different muscles—some doing this, some doing that. Hence it comes that in the limb are muscles which when they contract do with the limb exactly opposite things. Thus we find a set of muscles which bend the knee, and another which straighten the knee; so, similarly, at hip and ankle, at elbow, shoulder, and wrist. These muscles of opposed action are called antagonists. Now in the flexion reflex—the reflex we are considering—when the reflex bends the knee by causing the flexor muscles to contract, what happens with regard to the muscles which straighten the knee? Do the opponents, the muscles which straighten the knee, contract, or does the reflex nervous influence leave these muscles untouched? It used to be taught that the muscles which straighten the knee, the extensor muscles, contract, and by their contraction exert a moderating influence on the muscles which execute the flexion. That was the anatomical speculation deduced from simple dissection of the musculature of the dead limb. Experiment with the living limb teaches that nature does not expend her muscular energy in using the power of one muscle simply to curb the power of another. When the knee is bent the reflex act does not hamper the working of the flexor muscles by causing a contraction of the extensors also. Nor does it simply leave the extensors out of account. No; it causes them to relax and lengthen at the same time as it causes the flexor muscles to contract and shorten. This it does by reflex *inhibition;* and it proportions the grade of this relaxation exactly to the grade of contraction of the opponent muscles.

The inhibition acts, not on the muscle directly, but on the motor nerve-cells innervating the muscle. These nerve-cells are long filaments; one end of each lies in the muscle, the other in the spinal cord. The reflex inhibition is exercised upon them at the end which lies in the spinal cord. In the reflex we are considering, the reflex action, besides *exciting* the motor nerve-cells of the three muscle groups—flexors, abductors, and internal rotators—before mentioned, *inhibits* the motor nerve-cells of three muscle groups antagonistic to those, namely, the extensors, the abductors, and external rotators. We see, therefore, that in even the simple reflex lifting of the foot, almost every one of the many muscles composing the whole musculature of the limb receives from the nervous system a controlling influence, either of excitation to contract or of inhibition which relaxes contraction; and all this in result of a simple touch of the skin of the foot. The reaction typifies in a simple manner the action of the nervous system to knit the heterogeneous powers of the body together into one harmonious whole.

Thus we see that in these actions when one group of muscles contracts the group antagonistic to it relaxes. This is a fundamental part of the co-ordination of the act, and its discovery throws a welcome light on the nature of certain maladies. Were the antagonistic group to contract at the same time as the protagonist, the desired movement would not result. The movement which then ensued would depend on which of the two muscle groups were the stronger, the protagonist or the antagonist. The alkaloid strychnine and the poison produced by the bacilli which cause the malady called "lock-jaw" possess the power of destroying reflex inhibition. What the intricate nature of the process of this inhibition is we do not yet know, but it seems to be the exact converse of the process of excitation, the nature of which is also unknown. Strychnine and tetanus-toxin change the process of inhibition into its converse, namely, excitation. If a minute dose of strychnine be administered, the reflex which, as we saw, causes the limb to bend, now causes the limb to straighten instead. This is because the extensors, when the flexors contract, instead of being relaxed by inhibition, are excited to contraction, and being more powerful than the flexors move the limb in exactly the opposite direction to that in which it should move in this reflex action. Similarly with the toxin of "lock-jaw." The muscles which close the jaws are much more powerful than those which open them. In the normal act of opening the mouth the relatively feeble opening muscles contract, and the powerful closing muscles are simultaneously relaxed by reflex inhibition. But in an animal or man poisoned with this toxin the normal inhibition of the closing muscles is changed to the exactly opposite process of excitation, so that their contraction results. Against the power of these strong closing muscles the contraction of the weak opening muscles can effect little. Each time, therefore, that the sufferer tries to open his jaws to take food or speak, he clenches his jaws instead of opening them—experiencing a torture which, although unaccompanied by physical pain, is inexpressibly distressing; and the disorder leads to death from inanition.

But to return to the reflex lifting of the leg, whence we set out. It was mentioned that in this reflex the limb was not merely lifted, but was slightly rotated inward at the hip, and that the thigh was slightly abducted, that is to say, drawn sideways, separating it more from the fellow-limb of the opposite. These accessory movements have a significance coinciding with much other evidence into which we have not time to enter now. They, together with other evidence, show that this lifting of the leg, so easily produced reflexly, is nothing more or less than the first movement of the taking of a step. In fact, in our rough and imperfect analysis of this little movement, we have been examining part of the great and extraordinarily complex and perfect act which is called walking—or more technically, so as to include the cognate acts of trotting and running—locomotion. A little reflection will suffice to assure you that included in the action of locomotion is also that of standing. We are apt to forget that the muscles have a static as well as a kinetic action—that they are the instruments of maintaining position, as well as of the execution of movements. Directly we begin to analyze locomotion we see that its basis, as it were, is the position of standing, upon which movements of stepping are, as it were, grafted. Not much is known as yet of how animals and ourselves stand, walk, and run. In these acts, probably, every skeletal muscle in the whole body is concerned. Rheumatism can make us aware of that. A little receptor organ in the ear is a great factor in the whole matter. But of this we may be sure, that foremost in its factors are reflex actions of the limbs. Great economic questions are involved in this unraveling of the act of locomotion—all beasts of draft and burden are chiefly useful to us because they can stand, and walk, and run. We can only employ their powers to full advantage and with due regard to them as they unfold these powers when we shall have learned something of the way in which these movements are conducted and performed.

The crude and imperfect analysis which I have attempted to outline concerned but *one phase* of the step of a *single* limb. In the complete act the other limbs will at the same time be executing other phases of the whole cyclic reflex. The neck and trunk are also involved; so, likewise, the head itself. Our imperfect analysis threw sidelights on the nature of the mischief wrought by strychnine-poisoning and the malady "lock-jaw." Interesting and useful though these sidelights may be, more really interesting and valuable would be any light which such analysis, crude as it is, could throw on that great normal process of everyday health, animal (including human) locomotion. Analysis of the reflex movement in unconscious animals seems at the present time the only way by which such knowledge can be gained.

Coloring Strawberries.—Genuine carmine nacarat is recommended by the Konserven Zeitung as the best material for coloring strawberries, being the most effective for restoring the natural color. These colors, which are sold in solid pieces, are dissolved with spirits of sal-ammoniac. For this purpose it is best to use a porcelain or glass dish with a pestle of the same material. Sufficient pure water must be added to the carmine to form a thick paste. Then spirits of sal-ammoniac is added till the carmine is dissolved, which is shown by the paste taking on a deep red color. The pestle is of course used from the beginning of the operation for crushing the pieces of carmine and stirring the paste till it becomes fluid. Finally the solution is boiled and kept in well-corked bottles for better preservation.

THE STORY OF THE TOBACCO PIPE.*

THE WORLDWIDE DISTRIBUTION OF SMOKE TUBES.

BY T. P. COOPER.

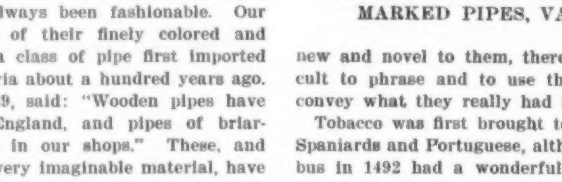
THE true and ardent Nicotian has ever adopted a pipe as the most perfect manner of enjoying the fragrant weed. In every clime and country the fumes of tobacco are inhaled through some kind of tube, and a collection of the world's pipes would contain more types of peculiarity than there are nations or tribes upon the face of the earth. Little more than a century ago a nation's pipes were, as a rule, made of the most suitable and available material found in their respective countries, and some peoples of necessity still adopt what seem to us very curious and strange devices.

The natives of the Arctic regions smoke through a walrus tooth; in Assam and Burma bamboo pipes are used; the tribes of New Guinea contrive sea shells as bowls for their pipes; the aborigine of New Zealand has an elaborately carved wooden pipe, embellished with the typical grotesque figures so familiar in the native art of that country; on the Yarkand River in Central Asia pipes are made of jade; the Hindoos mold their pipes of a rough red clay; the tribes of South Africa use wood, clay, bone, and soap-stone or steatite, as it is sometimes called; a long porcelain bowl is a favorite pipe head used by the Germans.

It is said that the earliest pipes adopted in England by the richer *habitues* were made of silver; some of the wealthy "puffers of tobacco" may have used such pipes, but the poorer classes "drank" their tobacco through a straw attached to a walnut-shell, which was indeed a very primitive device. The majority of early smokers in England soon became enamored of the white clay pipe, a "little tube of mighty power," which was almost universally adopted.

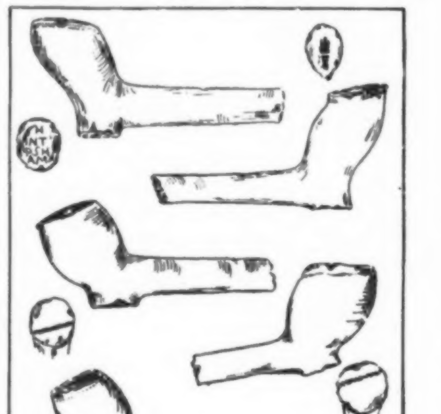
Present-day votaries of the "soverane herbe" who cherish their mellow meerschaums, their spicy cherry-woods, or their sweet briarwoods, inhale its soothing vapors with a thousand whiffs, in the happy delusion that such pipes have always been fashionable. Our forefathers were proud of their finely colored and polished meerschaums, a class of pipe first imported into England from Austria about a hundred years ago. Fairholt, writing in 1839, said: "Wooden pipes have been introduced into England, and pipes of briarwood are now common in our shops." These, and others made of almost every imaginable material, have gradually superseded the homely white clay, which was practically the Englishman's only pipe for upward of two hundred and fifty years.

There is no question that the habit or pastime of smoking tobacco in pipes was copied from the North American Indians, by early travelers and settlers. Like the aborigines, European voyagers smoked from pipes of stone and clay, and the same manner of smoking was subsequently introduced into England. The appropriation of the tobacco plant for smoking purposes was common among the native races of America long prior to the discovery of their continent by the whites. There was a sacredness and significance attached to the smoking customs of the Indians which were more than mere habit or common practice. The pipe was intimately associated with their national, social, and religious life; war was declared and warriors summoned by the reddened pipe of the chief, and treaties of peace were ratified as they "Smoked the Calumet—the Peace Pipe," a revered relic carried by each tribe, and handed down from generation to generation.



YORK PIPES AND MAKERS.

Most early travelers in writing their accounts and descriptions of the singular smoking customs of the Indians were very indefinite; the practice was entirely



MARKED PIPES, VARIOUS DATES.

new and novel to them, therefore they found it difficult to phrase and to use those words which would convey what they really had seen.

Tobacco was first brought to Europe in 1518 by the Spaniards and Portuguese, although the crew of Columbus in 1492 had a wonderful story to relate of how they had seen the natives inhaling smoke and puffing it out again. The honor of importing tobacco into England and setting the fashion in smoking has been assigned to Sir Walter Raleigh, who returned home in 1586. In a very few years the singular practice spread rapidly throughout Europe, and to the farthermost corners of the inhabitable globe. The first mention of pipes was in 1564, where Sir John Hawkins describes the Floridians smoking a herb "with a cane and an earthen cup." Thomas Hariot, who accompanied Raleigh's expedition to Virginia in 1584, when speaking of tobacco, says: "The leaves thereof are dried and brought into powder they use to take the fume thereof by sucking it through pipes made of clay."

The United States National Museum contains many hundreds of aboriginal pipes, collected from all parts of the American continent, and many of these are figured and described in a critical work by Mr. Joseph D. McGuire.*

A straight funnel or tube-shaped pipe found in America, a type which appears common to the whole country, is supposed to be the most primitive and earliest kind of pipe used. Some writers have referred to a Y-shaped pipe, which was thought to have been the earliest type of instrument used in America for smoking, but only a few specimens have been found. Straight tubes are the most ancient pipes, and these vary in both length and diameter, as well as in the materials from which they are made; many of bone, stone, earthenware, and wood, not unlike cigar-holders, have been unearthed on the Western Continent.

Smokers, no doubt, soon improved on this form, as hundreds of relics testify, and the evolution of the tubular pipe into one of rectangular shape came by gradual stages. The shapes of early American pipes differ greatly with the locality where they occur. Some strange expedients were adopted in the choice of bowls; singular pieces of stone which attracted the curiosity of the Indians were sometimes hollowed and carved. Representations of birds, animals, and reptiles often adorned the bowls and short stone stems, into which longer tubes were inserted. One remarkable example, a fossil pipe of hoary antiquity, presents a strange blending of nature and savage art. Their pipe stems were made of bone, horn, ivory, wood, stone, and quills, and were frequently highly decorated.

The English adopted the idea of pipes from the aboriginal races of America, and they soon found that cheaper and better pipes could be made of clay. The typical "English clay" appears to have been made within a year or two after the introduction of tobacco smoking by Raleigh in 1586. Paul Hetzner, a German lawyer, who visited England in 1598, notes with surprise the use of clay pipes. At the Bear Gardens, Southwark, "and everywhere else the English are constantly smoking, and in this manner—they have pipes on purpose, made of clay."

Sailors, who learned the use and virtues of the sublime weed, and also introduced it into England, have always been inveterate smokers. The fragrant fumes appealed to them as a wonderful solace during the privations of a seafaring life, beguiling idle hours and weary watches on shipboard, and very appropriately we find a ship called "The Tobacco Pipe." On May 5, 1599, a sailor named Edmund Saunders, of Weymouth and Melcombe Regis, was examined before John Mokel, mayor of Weymouth, and other magistrates, at Waterhouse, where the sailor deposed that when on board the good ship "The Tobacco Pipe" in Bordeaux Harbor, one Henry Carye said that "he could find in his heart to be 'the Queen's' hangman, and to hang her at the yardarm." These disloyal and seditious words were revealed to Richard Toms, the master of the ship, hence the examination, a report of which was sent to Queen Elizabeth's advisers at court.

Many references to tobacco are found in the correspondence of this period. John Watts, an alderman of London, in a letter written to Sir Robert Cecil, Secretary of State, who must have learned the practice of "drinking tobacco," as smoking was spoken of, says: "According to your request, I have sent the greatest part of my store of 'tobaca' by the bearer, wishing that the same may be to your good liking. But this 'tobaca' I have had this six months, which was such as my son brought home, but since that time I have had none. At this period there is none that is good to be had for money. Wishing you to make store thereof, for I do not know where to have the like, I have sent you of two sorts. Mincing Lane, 12 Dec., 1600."

At first smoking in England was only indulged in during hours of leisure and in private, but the habit became so popular that smokers in the streets were everywhere met. A writer of the times tells us that:

"Tobacco engages
Both sexes, all ages—
The poor as well as the wealthy;
From the court to the cottage,
From childhood to dotage—
Both those that are sick and the healthy.

. . .

"It plainly appears
That in a few years,
Tobacco more custom hath gain'd
Than sack or than ale,
Though they double the tale,
Of the time wherein they have reign'd."

. . .

* The Reliquary and Illustrated Archæologist.

* Pipes and Smoking Customs of the American Aborigines, based on material in the United States National Museum, 1889.

King James I. detested the newly acquired smoking habits of his subjects, and in 1603 he issued his famous tract, the "Counterblaste to Tobacco," wherein he condemned smoking, and described it as "a loathsome custom"; he finishes his diatribe by saying, "the black, stinking fume thereof nearest resembling the Stygian smoke of the pit that is bottomless." The King's expressed dislike to tobacco and his denunciatory epistle doubtless acted as an incentive to the populace in their public and persistent use of the potent weed.

One often wonders if Shakespeare puffed the social pipe, as it is a curious fact that no allusion to tobacco, smoking, or pipes is to be found in any of his plays, although contemporary dramatists indulged in jests at the lately imported herb. Pipes were used and certainly smoked under the very nose of the players in the theaters. The Bard of Avon, being the favorite playwright of James I., may have obsequiously omitted all notice of it to please his royal master.

King James and his court journeyed to Winchester in November, 1603, and Sir Walter Raleigh, who was so harshly treated by this monarch, was among the persons to be tried at the castle for complication in the "Main" and "Bye" plots. When Raleigh arrived, the citizens were full of admiration for their new King, and as the disgraced knight, amid the jeers and taunts of the people, was led through the streets to his trial, he was in derision pelted with tobacco pipes.

So rapidly had smoking gained favor that the demand for pipes early created a flourishing trade. Philip Foote, of London, in 1618 obtained a license to sell clay for making tobacco pipes for twenty-one years. A little later William Foote was granted a patent "of the privilege of selling pipe clay, the former patentee being dead, and bad clay sold by others."

The seventeenth century was an age of monopolies, and a colonel named William Legge, in 1666, appealed for a grant for the making and selling of tobacco pipes in Ireland, as persons had in previous years obtained royal letters patent for the sole rights of retailing tobacco in various towns and districts. The Tobacco Pipe Makers' Company enjoyed the monopoly of making pipes in 1601, which guild, however, was not regularly incorporated until 1619, and, appropriately, the company's motto was "Let brotherly love continue." A royal proclamation issued May 5, 1639, commanded that no tobacco pipe clay had to be "water-borne or transported in anywise." The charge of land-carriage of the clay was detrimental to the trade, and severely felt by the pipe-makers of towns remote from clay pits, which necessitated the search for other suitable clays. The unreasonable edict was subsequently repealed. In 1667 "three west countrymen (ships) laden with tobacco clay, bound for Lynn," were anchored at Yarmouth waiting for a convoy. England was at war with the Dutch, and the enemy's ships sailed up the Medway and burned the English men-of-war, hence the need of a convoy for merchant ships, which were often captured and carried off.

The Company of Tobacco Pipe Makers in 1663 petitioned Parliament "to forbid the export of tobacco pipe clay, since by the manufacture of pipes in Holland their trade is much damaged"; they also requested "the confirmation of their charter of government so as to empower them to regulate abuses, as many persons engage in the trade without license." Their prayer was granted, with a proviso that in future in the firing or baking of pipes only coal should be used as furnace fuel. In the following year the guild again addressed Parliament, "showing the great improvement in their trade since their incorporation, 17 James I., and their threatened ruin because cooks, bakers, and ale-house keepers, and others make pipes, but so unskillfully that they are brought into disesteem; they request to be comprehended in the Statute of Laborers of 5 Elizabeth, so that none may follow the trade who have not been apprentices seven years."

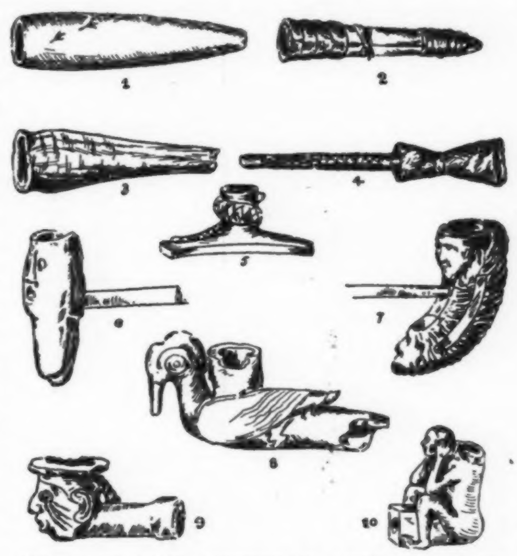
The craft of pipe-making flourished in all the chief towns of England as well as in the metropolis; Winchester, York, Exeter, Bath, Bristol, Hull, and many other places had their pipe-makers. Broseley in Staffordshire has pre-eminently retained its notoriety for pipes of superior quality, which have been famous since the time of Elizabeth.

That tobacco pipes were made at Exeter in 1654 is curiously proved by the following case of supposed witchcraft: "12 August, 1654, one Diana Crosse, a widow, suspected of being a witch, was ordered by the Judge of Assize to be committed for trial at the city sessions. Mr. Edward Trible, a tobacco pipe maker, one of the victims of the witch's arts, deposed that Mrs. Crosse on one occasion came to his house for fire, which was delivered to her, but for the space of one month afterward he could not make or work his tobacco-pipes to his satisfaction—they were altogether either over or under burnt." A Frenchman, writing in 1688, records that the English "invented the pipes of burnt clay which are now used everywhere." The Dutch learned the art of pipe-making from England, and they imported English clay, which was returned to us in manufactured pipes to the annoyance of the Pipe-makers' Company.

The first clay pipes made were extremely small, and these, with pipes of subsequent periods, are often turned up during excavations; they are sometimes picked up in localities where Parliamentarian soldiers have encamped, and they are frequently unearthed by

CURIOUS MARKS ON THE HEELS OF OLD PIPES.

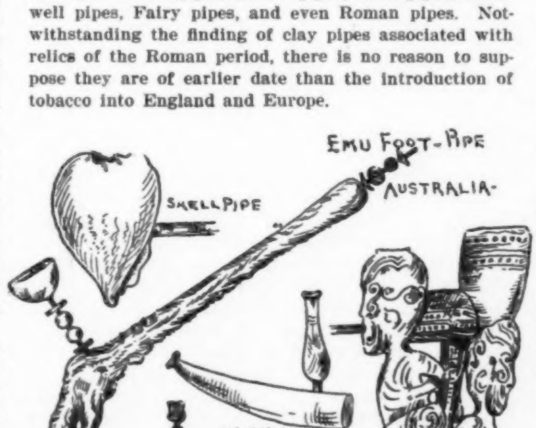
plowmen. Often in the suburbs of large towns, where grass fields are being appropriated for building purposes, they are found beneath the turf, having been carted out with manure from old inns and taverns centuries ago. During the plague smoking was esteemed a preventive against infection, and disused pipes were thrown into burial pits and churchyard



PIPES OF THE AMERICAN ABORIGINES IN THE UNITED STATES NATIONAL MUSEUM.

1. Ancient stone tubular pipe, from Wilkes County, Georgia. 7 inches long. Diameter, 1¾ inches at the widest part. The incised ornamentation—tracks of a bird. 2. Comanche bone pipe, wrapped with strips of raw hide. 3. Unfinished tubular stone pipe, found at Newport, Cook County; 4¾ inches long; exterior diameter at thickest part, 1⅛ inches. 4. Wood and stone pipe, from the Hupa reservation; 11 inches long. 5. Mound snake pipe, from Mound City, Ohio; 3 inches long. 6. Banded-slate bowl pipe, from West Virginia; 2 inches high. 7. Fossil pipe, from Pottawatomie, Kansas; about 4 inches high and made of the outer whorl of an ammonite. 8. Steatite pipe, from Cumberland County, Tennessee, representing a wood duck; 9 inches long, 4 inches high. 9. Cherokee stone pipe, from Bradley County, Tennessee, representing the head of an Indian; 3 inches long. 10. Wood and lead pipe, from Rhode Island; 3 inches long, 4 inches high.

graves. These old pipes have been given many strange names by rustics and uneducated people—they are known as Celtic pipes, Danes' pipes, Elfin pipes, Cromwell pipes, Fairy pipes, and even Roman pipes. Notwithstanding the finding of clay pipes associated with relics of the Roman period, there is no reason to suppose they are of earlier date than the introduction of tobacco into England and Europe.



ABORIGINAL PIPES.

Old English "clays" are exceedingly interesting, as most of them are branded with the maker's initials. Monograms and designs were stamped or molded upon the bowls and on the stems, but more generally upon the spur or flat heel of the pipe. Many pipes display on the heels various forms of lines, hatched and milled, which were perhaps the earliest marks of identification adopted by the pipe-makers. In a careful examination of the monograms we are able to identify the makers of certain pipes found in quantities at various places, by reference to the freemen and burgess rolls and parish registers. During the latter half of the seventeenth century English pipes were presented by colonists in America to the Indians; they subsequently became valuable as objects of barter or part purchase value in exchange for land.

In 1677 one hundred and twenty pipes and one hundred Jew's harps were given for a strip of country near Timber Creek, in New Jersey. William Penn, the founder of Pennsylvania, purchased a tract of land, and three hundred pipes were included in the articles given in the exchange.

Old English pipes, which the Americans call "trade pipes," are occasionally found on the sites of Indian villages and in burial mounds. From the great number of "clays" so picked up bearing the initials T.D., the modern clays used in America are vernacularly known as T.D.'s.

A Yankee enthusiast writes in praise of his familiar "T.D." in the following manner:

"You may take the meerschaum with amber bit,
And the briar too—for not one whit
Will I miss them after a day or two;
But without the other I could not do,
For some bond holds us, don't you see?
I never could part with my old 'T.D.'
A bond of friendship that seems to grow
With the years that come, and the years that go:
A something mingling our lives in one—
Old tasks performed, new works begun,
And sometimes musing I sit and think,
What binds us fast to this friendly link?
While then, in answer it seems to say—
'Old pal, we both have been formed from clay.'
Then I understand how it comes to me,
This love I bear for my old 'T.D.'"

The form, shape, and size of the English clay pipe have passed through a certain evolution since it was first adopted in the sixteenth century. The stems of the earliest were about nine inches, longer clays with stems tipped with glaze were introduced about 1700 and called "Aldermen." The "Churchwarden"—the unadulterated "yard of clay"—came into fashion about 1819, and was indeed typical of a leisurely smoke. For work-a-day use the shorter Irish dudeen and Scot's cutty still survive; but whether we inhale tobacco's soothing cloud through clay, briar, cherry, or meerschaum, we gratefully exclaim with Dr. Garth:

"Hail! social pipe—thou foe of care,
Companion of my elbow-chair;
As forth thy curling fumes arise,
They seem an evening sacrifice—
An offering to my Maker's praise,
For all His benefits and grace."

MODERN PHYSICS.*

By PROF. ERNEST FOX NICHOLS, Columbia University.

THE ideas which underlie all our thinking are space, time, and inertia or mass. With space and time as a background, the physicist must pursue inertia and everything related to it, along every conceivable path. In this pursuit he comes upon four ultimate though related conceptions: matter, ether, electricity, and energy.

At bottom, I suppose, the ether, electricity, force, energy, molecule, atom, electron, are but the symbols of our groping thoughts created by an inborn necessity of the human mind which strives to make all things reasonable. In thus reasoning from things seen and tangible, to things unseen and intangible, the resources of mathematical analysis are applied to the mental images of the investigator, images often suggested to him by his knowledge of the behavior of material bodies. This process leads first to a working hypothesis, which is then tested in all its conceivable consequences, and any phenomena not already known which it requires for its fulfillment are sought in the laboratory. By this slow advance a working hypothesis which has satisfied all the demands put upon it gradually becomes a theory which steadily gains in authority as more and more new lines of evidence converge upon it and confirm it.

If we now consider more closely the nature of the conceptions matter, ether, electricity, and energy, we shall later find that matter, ether, and electricity possess some attributes in common, and if we take careful heed to what we shall understand by the word, we may call them substances. Energy appears as the measure of their possible interactions.

Taking energy first: All the numberless changes we see taking place in the universe are, we think, manifestations of the interactions among matter, ether, and electricity. With every changing aspect of nature

* Abstract of a lecture delivered at Columbia University, in the series on Science, Philosophy and Art, as the opening lecture in the natural science group. Republished from the Popular Science Monthly.

energy is passing from body to body and undergoing incessant transformations, but its amount is always measurable by the work it may accomplish when harnessed.

Our knowledge of the uncreatable and indestructible character of energy has given us a universal test which we may freely apply to all phenomena to prove our knowledge of them. For when the required energy relations are not satisfied by our explanations, it means we have not got to the bottom of the case, but must strike deeper in to realize the whole of the concealed mechanism.

Charmed by the simplicity and sweep of the law of the conservation of energy, a small school of physicists, who have mostly entered in by the door of physical chemistry, have frankly set energy before inertia, and have endeavored to deduce matter and all else from it. This of course can be done, for physics has become a body of thought so closely knit together that all things in it are somehow related. Seen broadly, however, the new method has few obvious advantages over the historic procedure and not a few evident defects.

Matter has two indisputable hallmarks, two properties in the possession of which all the infinitely varied forms of matter unite, inertia and weight. By inertia we mean that active resistance shown by every piece of matter to any effort to change its motion; while the mutual attraction between all material bodies, according to which all matter strives to collect itself into one huge compact lump, we call gravitation. The gravitational pull of the earth upon a portion of matter is its weight. If we find anything in the world, however strange, which possesses both inertia and weight, we may call it matter without further examination.

The ether which surrounds and incloses all our universe we came first to know as the bearer of waves of light and heat. Ever since that time we have known it to possess inertia; for no medium devoid of inertia can carry forward a wave motion.

Thus the ether has one of the hallmarks of matter. Has it also weight? This we can not hope to know until we find some way as yet undiscovered to alter the natural distribution of ether between two portions of space. Here it should be remembered that the weight of gases was first proved after the invention of the air pump and barometer. But, alas! how shall we go about building an ether pump when all material walls seem more porous to the ether than the coarsest sieve is to air? And worse, the ether appears to be incompressible. The question of weight is thus at present in abeyance and we leave it.

Of the properties of electricity alone, it is still difficult to speak. The subject is easiest approached from the relations of electricity to ether on the one hand and the relations of electricity to matter on the other. It is in this last and more complicated phase of our subject that the most brilliant advances have recently been made.

To state the case between electricity and ether, we must begin with Faraday, and some of the mental images he formed of the connection between them, which have proved at once the most simple and useful aids to thought to be found in the whole history of physics. Faraday realized as well, perhaps, as we do to-day that electricity could no more be made outright than could matter. The utmost which could be done was to separate positive and negative electricity. If, therefore, any one exhibited a positive charge, there was somewhere in the universe an equal negative charge, to which it was drawn by invisible means across the intervening space.

Faraday maintained the forces of attraction were due to some kind of strain in the ether lying between. To picture the more vividly to himself and to others, the character of the stresses in this medium transmitting the force which one charge exerts upon another, he supposed contractile filaments called lines of force to traverse the ether between the charges. To make the case more definite he gave direction to these lines, assuming that they originated on the positive charge and terminated on an equal negative charge near by, or far away, according to circumstances.

The motions of electric charges when free to move, and the distribution of stresses in the ether round about, show that all happens as if each line of force were pulling like a stretched elastic thread to shorten itself and draw the charges together, and at the same time unlike any elastic thread we know, it was repelling or pushing sidewise at the other force lines near it.

If a charge of positive electricity be given to a metal sphere, and the negative charge from which it has been separated be dissipated to remote bodies or be carried so far away that its position is no longer of any immediate importance, lines of force will start from the spherical surface of the conductor in all outward directions, and will be precisely radial. As many lines will leave from any one half of the sphere as from another. This equal radial arrangement of the lines of force is produced by the sidewise shoving of each line of force upon its neighbors until the stresses in the ether at the bounding surface of the metal are equal on all sides.

If now the metal sphere with its charge be put in steady motion, it will carry its lines of force along with it, and if the motion be not too swift, all the lines of force will continue radial. But with this motion of the lines of electric force through the ether, a wholly new and additional ethereal force appears—a magnetic force which did not exist when the charge was at rest. This magnetic force is always at right angles both to the lines of electric force and to the direction of their motion, thus encircling the moving charge. The planes of these circles are perpendicular to the straight path along which the charge is traveling.

As long as the motion and charge remain uniform there will be no change whatever in this magnetic force except that it keeps abreast of the sphere as do the moving lines of electric force on which it depends. As soon as the motion ceases, the magnetic force disappears and soon all is as it was before the motion began. But while the sphere is starting or stopping, before it has reached its steady motion, or while it is coming to rest, the electric and magnetic forces are undergoing readjustment, and this disturbance spreads outward through the ether with a speed precisely equal to the speed of light. Nor is this a chance agreement, for we know that light consists of nothing more than very rapidly and periodically changing electro-magnetic forces traveling out through the ether from a particular source of electric disturbance, called a luminous body. The ethereal phenomena we have noted around a moving charge faithfully repeat themselves about a wire carrying an electric current and it was here that Faraday found them.

To the mental images of Faraday—these lines of force which helped him to grapple with the unseen, to form working hypotheses, to experiment—to these Maxwell applied the powerful resources of mathematical analysis and reared the splendid structure of the electro-magnetic theory. Now that the work is done we may let fall the scaffolding which Faraday's vivid imagination supplied, but we could not earlier have done without it. Here we have the whole chain, mental image, hypothesis, experiment, theory.

As we now take up what we believe to be the relations of electricity to matter, we come in places upon slippery ground and the bases of our faith rest on recent foundations.

At the outset we encounter one striking difference between electricity and matter. Every free charge exerts a force upon every other charge in the universe, just as every particle of matter exerts a force on every other particle of matter however distant. But with matter the particles are invariably urged toward each other while electric charges may be either drawn together or forced apart, depending on the kinds of charges. We have both positive and negative electricity, but only one kind of matter.

Just how these two kinds of electricity are different we know little beyond the invariable law that positive attracts negative and repels positive. In some ways positive and negative electricity resemble right and left-handed things. If the same number of right and left-handed turns be given to a screw, one hand will precisely undo the work of the other. If the right and left hands be brought together they fit part for part, but two right gloves are a poor pair. On the contrary, there is no right and left to gravitation. Two pieces of matter always fit in the gravitational sense.

The bald statement of the laws of gravitation and electric force bear a strong resemblance to each other. The laws tell us how the forces vary, but reveal no hint of the machinery by which they act.

Gravitation was the first force man encountered, and it is still the one he knows least about, for we have got no farther than where Newton left it two and a half centuries ago. We have some inkling of the possible machinery by which one electric charge acts upon another at a distance, and we feel nearly as sure that the push or pull is carried by the ether as that the pull of a horse on a cart is through the traces which bind him to it. With gravitation the case is very different, for we have not as yet the slightest valid conception of how the pull of one mass upon another is conducted across the intervening space, nor what conducts it. We can get no farther until the speed with which gravitation disturbances travel has been measured, and no one at present seems to know how to go about making such an experiment.

One further difference between gravitation and electric force. The force of attraction or repulsion between two charges of electricity is diminished by replacing the free ether between them with any material medium, but the force of gravitation between two bodies remains constant as long as the distance remains constant, and intervening masses are powerless to shield or to alter it. Hence we can not yet attribute the gravitation of matter to any electricity which may be contained in it, nor prove the ether to be the medium through which the force acts.

Gravitation is still unconnected, unattached to anything else in nature; as independent as Mr. Kipling's "cat that walked by himself, and all places were alike to him." It is still the stumbling block to the physicist which it has been these many years. How can he explain a universe when he is unable to give a reasonable account of the cement which holds it together?

Of the intimate association of electricity with matter we have learned much from careful study of the processes of electric conduction in solutions and gases.

When a simple chemical compound (and it should here be borne in mind that the molecule of a compound is built up of atoms of at least two different kinds)—when a simple chemical compound, hydrochloric acid for example, is dissolved in water and an electric current is passed through the solution, the products hydrogen and chlorine of the decomposed acid appear in definite proportions at the points where the current enters and leaves the liquid—the chlorine where the current enters, the hydrogen where it leaves. We know this current to consist of processions of single charged atoms, a disorderly march, perhaps, with a crowd of bystanders obstructing the way, but the movement is always forward, each constituent of the broken molecule carrying a definite electric charge. These processions are always double, the atomic carriers of the positive charge moving in one direction, those carrying the negative charge in the other. The same quantity of positive electricity is carried by one procession, as negative electricity by the other. We have not only measured the charge carried by a single atom, but the average speed with which the atoms traverse the solution. It has been found, further, that atoms of the different chemical elements having the same mating value, technically called valence, always carry the same unvarying charge, whether the atoms themselves be light or heavy. These charged atoms, in some cases atom groups, are spoken of as ions.

Such electrolytic experiments as these have led to two surprising results. First: no electric charge smaller than that carried by an atom of the hydrogen valence has yet been found. Second: all other small charges are exact multiples of this value.

We have long been familiar with the idea of atoms of matter, but here for the first time we come across something which looks very like an atom, or natural unit, of electricity. The justification for calling it an atom of electricity is like the argument for the atom of matter. Moreover, we know some eighty different kinds of material atoms, but only two kinds of electric atoms, a positive and negative. Thus the electric atom of the two has the greater claim to simplicity. When we speak of an electric atom disregarding for the time the matter associated with it, we call it, not an ion, but an electron. Evidence will later be given suggesting ways by which we may wrench a negative electron wholly free from matter, and experiment with it in its detached and pure state.

We are now in a position to consider the rôle electric forces play in holding atoms together within a compound molecule, for, from the foregoing, it appears when a molecule is broken in two, the fragments are always found equally and oppositely charged, and they doubtless held these charges within the molecule. But the distance separating the two parts was then so small that all the lines of force from the positive charge ended at once on the equal negative charge, and no force lines strayed beyond the molecule boundary. Hence no evidence of an electrical charge could be found in the ether outside the molecule. It seems probable, therefore, that the electric force between the atoms of matter in the molecule supplies the chemist with the cement he has long called chemical affinity.

The ratio of the electric charge to the mass of the particle on which it rides (in our processions) has come to be one of the most important quantities in physics. As we know both the quantity of matter and quantity of electricity transferred by a given electric current, we can express this ratio for each chemical element. Hydrogen gives the largest ratio found in solutions.

Systematic study of the conduction of electricity in gases is of more recent origin, but the knowledge gained from it not only confirms the ideas formed to explain conduction in solutions, but has very widely extended and simplified them. The chief difference between electric conduction in solutions and conduction in gases arises from the large number of broken molecules or ions always present in solutions. These require only the presence of an electromotive force to start them marching, but a gas, in its natural or nonconducting state, contains very few ions, not enough to support even a very small current, and for this reason gases are insulators.

In gases, however, there are many ways of making ions, X-rays, radium rays, rays of ultra-violet light on metals, combustion in flames, white-hot bodies of every sort will do it. But there is one method which depends on the violent collisions of ions with mole-

cules which is so objective in its form I can not forbear attempting to describe it. It is also the method which leads us to cathode rays and much more.

Imagine, then, a glass tube into each end of which a conducting rod carrying a small metal disk is sealed. These rods may at will be connected to the terminals of a battery. If while the tube is filled with a gas, in its non-conducting state, the battery be applied, the very few ions always present are set in motion, but the too frequent collisions in the swarm of neutral molecules which obstruct the way prevent the moving ions from attaining more than moderate speeds.

By connecting the tube to an air pump as many as we like of the interfering molecules may be removed. As more and more gas is drawn out of the tube, the moving ions encounter fewer and fewer collisions, and in consequence attain higher and higher speeds, as small shot might fall through a gradually dispersing swarm of bees poised in midair. The longer the pumping is kept up the greater the maximum speed of the ions becomes and the more violent are the collisions which do occur. When nearly all of the gas has been drawn out of the tube, a stage is reached where the encounters between flying ion and indifferent molecule become so violent that molecules are shattered and new ions produced, which in their turn work more destruction.

When this stage is reached, the gas is a good conductor, but if the pumping be carried too far, a second stage appears in which the encounters are too few to make enough new ions to support the current, and the gas finally ceases to conduct systematically. It is near the end of the conducting stage that the much-discussed cathode rays appear. They depart from the cathode or metal disk in the end of the tube connected to the negative side of the battery.

The extraordinary resourcefulness, shown by the leading workers in this field of recent inquiry, in untangling the complex snarl of phenomena presented, marks a very great achievement. So inspiring from the human side as well as the physical has been this unequal contest of man with nature, of mind struggling against disorder, and so bravely done, that I ask your indulgence while I try for a few minutes, fragmentarily, to describe one or two fundamental experiments.

Cathode rays are invisible, but many substances—fortunately glass is of the number—shine with a bright phosphorescent light when placed in the path of the rays. By this means it was early discovered that cathode rays travel in straight lines which always leave the cathode making right angles with the metal surface from which they depart. It is possible, therefore, to make the cathode concave or saucer-shaped and thus bring the rays to a focus at some point in the tube. If cathode rays are thus focused upon the blades of a very delicate paddle wheel which rotates easily upon an axis, the wheel is set revolving as if struck by a stream of moving matter.

The rays are found to possess an unusual power of penetrating matter impervious to light. They will even traverse a considerable thickness of aluminium. A comparison of the absorbing powers of different materials for cathode rays shows absorption to be roughly proportional to the density of the substance.

There is a field of magnetic force about a beam of these rays and this added to the transfer of electricity along the path gives to the cathode stream the distinguishing marks of an electric current in a wire or a procession of electrically charged bodies. If a magnet be brought near the tube the cathode stream is deflected from its direct course. This deflection by the magnet shows three things: First, cathode rays are not of the nature of light rays, the path of which a magnet is powerless to change. Second, the curved path which the stream follows again shows the stream to possess inertia. Third, the side to which the rays are deflected indicates a stream of negative electricity.

Strongly electrified bodies brought near the tube also deflect the rays. It is possible to determine the speed and the ratio of charge to the mass of the cathode particle, by measurements of the curvature of the path due to the combined magnetic and electrostatic deflections. Speeds as high as one-tenth the velocity of light or 100,000 times the speed of a modern rifle bullet have thus been observed. The ratio of charge to mass comes out nearly a thousand times that found for the hydrogen atom by electrolysis. If the charge on the cathode particle is no longer than that on the hydrogen atom, which was called an atom of electricity, then the inertia or mass of these particles is only one one-thousandth part of the mass of hydrogen atoms.

The nature of cathode rays was thus determined, but at this stage it was all important to catch a known number of these missiles and measure the electric charge each carried. As the estimated size of these minute bodies is less than one ten-million-millionth of an inch, direct counting would be both slow and difficult, yet by one of the most ingenious experiments ever performed, Prof. J. J. Thomson did it, indirectly.

To bring the essential features of this remarkable experiment before you, I must begin some way off by reminding you of several things you already know. For instance, the quantity of water vapor which a given volume of air at ordinary pressures can hold without depositing it as a mist or rain increases with the temperature. If air inclosed in a vessel is allowed to expand suddenly its temperature falls. If the air were initially saturated with water vapor, after the expansion some of the vapor will go into mist or rain, provided any nuclei are present upon which the excess vapor can condense. In the ordinary fog or shower the dust particles always present in the open air act as nuclei for the formation of drops. Small free charges of electricity or ions serve the same purpose and the negative ions are more effective condensers than the positive, hence they come down first.

In a complicated vessel, which need not be described, Prof. Thomson admitted dust-free air saturated with water vapor. This mixture was allowed to expand several times to make sure of freeing it from accidental dust or ions which might be present. The former pressure was then restored and the gas ionized by admitting X-rays through the thin aluminium lid of the gas chamber. The next expansion, chosen sufficient in amount to cause condensation on the negative but not on the positive ions, caused a copious cloud of mist which gradually settled by its own weight to the bottom of the vessel. The top of the cloud as it fell was sharply defined, and its rate of descent could be measured.

Sir George Stokes many years before had calculated the rate of fall of small spherical bodies through air, and one needed to know only the density of a small sphere and its rate of fall to compute its size. The approximate volume of the individual drops could thus be found. The quantity of water in the whole shower could also be easily determined, hence the number of drops, equal to the number of negative ions upon which they might form, could be calculated.

In another way Prof. Thomson could measure the total quantity of free negative electricity present in the chamber when the fog was precipitated. He had thus the number of negative ions and the sum of their charges, and therefore the charge each carried.

The charge Prof. Thomson found as the result of his brilliant experiment was the atom of electricity over again. After this it was impossible to escape the conclusion that the bodies flying in the cathode stream were masses no greater than the one one-thousandth part of the hydrogen atom. Thus matter, or electricity, or something exists, which measured by inertia is a thousand times smaller than the lightest known atom of matter. Furthermore, the kind of gas in which the cathode discharge took place had no effect upon either the charge or the mass of the particles, which bear no observable earmarks to reveal the kind of matter out of which they come. Whatever their source, they are always the same.

So far as we now know, the cathode particle or negative electron is a minute portion of pure negative electricity, wholly free from matter. An atom of electricity, and nothing more. Its small inertia can be wholly explained to be of the kind electric charges borrow from the ether which surrounds them.

When electrons driven at high speeds down the cathode stream are suddenly stopped by striking a target of dense matter like platinum, the point where the target is struck becomes a source of X-rays. We have already seen that a moving electric charge when brought to rest sends out a pulse of electro-magnetic disturbance in the surrounding ether, and the greater the suddenness with which the motion is arrested, the sharper and more abrupt is the shock to the ether.

In one sense the principal difference between X-rays and the yellow light from a sodium flame is analogous to the difference between the air disturbances caused by an irregular jumble of sharp thin reports of small percussion caps, and the droning of a heavy organ pipe. One is a tangle of single shocks, the other a steady wave motion. Thus regarded, nearly all the remarkable properties of X-rays find a reasonable and easy explanation.

Turning now to the positive terminal of the tube: Under suitable conditions of experiment it is possible to get a stream of particles from it. Named as children are before their natures are in the least understood, these rays were called *canal* rays. Like cathode rays, they consist of flying missiles, but carry positive instead of negative charges. Compared with cathode rays, their speed is very moderate and the ratio of charge to mass is of the same order as that for the lighter atoms in conduction through solutions. This ratio varies somewhat with the kind of gas in the tube. Thus canal rays are probably a stream of material atoms which have lost one or more negative electrons.

All efforts to obtain a charge of positive electricity free from matter—a veritable positive electron—have thus far failed.

The extreme complexity of the material atom is strikingly shown by the light from incandescent gases and vapors. When examined by the spectroscope the single element iron exhibits hundreds of definitely placed bright lines in the visible spectrum alone, which means the iron atom must be capable of vibrating in hundreds of different periods. No single atom need be vibrating in all these ways at the same instant, but if all iron atoms are alike, and we have every reason to believe they are, whether shining on earth or in the stars, then every atom of iron must be capable of swinging or bounding, revolving or shuddering, or doing something in all these ways.

Before the evidence of the spectroscope the older idea of the atom as a simple structureless body falls to the ground. The complexity of a grand piano seems simple in comparison with the iron atom. But spectroscopic evidence does not end here, but indicates *what* it is in the atom which does something and *how* it does it.

Ten years ago Prof. Zeeman placed a sodium flame between the poles of a powerful electro-magnet and examined its light by the spectroscope. He observed the most striking and peculiar effects of the magnetic force on the character of the light. The time is too far gone to permit a description of what the effects were, but the light sent out by the flame showed exactly the characteristics which magnetic force would produce, provided the light came from atoms inside which minute electric charges were rapidly revolving. It was even possible to compute the ratio of charge to mass for these revolving mites. The ratio revealed was that previously obtained for the cathode particle.

Hence the mechanism which enables the material atom to emit light may be the same electron we met flying through the vacuum tube, now revolving in an orbit about the atom center as a planet revolves about the sun. Thus the chief difference between the atoms of one chemical element and those of another, may lie in the number and arrangement of electrons in a revolving system.

It had long been known that hints about the internal fabric of the atom would be most effectively sought with the spectroscope, but we have here gained at a single bound the most amazing insight into a most complex system. Here also we meet another of those astonishing previsions of Faraday. He tried Zeeman's experiment over fifty years ago, but was balked in his quest by the inadequacy of the instrumental equipment of his day.

The quite recent discovery of the wholly new and unsuspected property of radio-activity in a group of heavy elements has done much to confirm the views already expressed of the connection between electricity and matter, and much more, for radio-active phenomena suggest for the first time that some kinds of matter are not only unstable, but mutable.

Taking radium as the most highly developed example of its class, we find it, with the help of its numerous progeny, sending out three distinct types of rays, which for convenience of classification have been called α, β, and γ rays.

α rays closely resemble canal rays. They carry positive electric charges and possess a mass or inertia comparable with that of the helium or hydrogen atom.

β rays appear identical with cathode rays. They consist of negative electrons hurled out at speeds as great as nine-tenths the velocity of light.

γ rays are of the nature of X rays—a purely ethereal phenomenon. All these rays penetrate matter to varying depths, and absorption varies with density as in cathode rays.

α, β, and γ rays all have the power of wrenching electrons free from substances which absorb them. By this power to ionize gases a wholly new method of chemical analysis has sprung up—the method of analyzing by the electroscope. So marvelously delicate is this new radio-analysis that one part of radium in one hundred-million-million parts of uranium cannot escape detection. The electrometer test for differentiating the various radio-active substances is the time required for the fresh product gained by chemical manipulation to lose half its ionizing power. This important characteristic of each substance is disparagingly called its *rate of decay*.

By the aid of the new analysis, Rutherford and others have found that radium is slowly disintegrating into radium emanation, which in turn changes into a distinct substance called radium A, and so on by successive steps down the alphabet to radium F, which is possibly a parent of lead. Helium appears also as a by-product of radium disintegration. From radium downward each of the seven substances has a characteristic rate of decay ranging from 1,300 years for radium, to three minutes for radium A. Radium emanation is a gas which liquefies at —150 deg. C. Some of the later products seem to be solids.

Is it not amazing that any of the properties of these six derivative products should be known at all, when never yet has one of them been seen, nor weighed, nor caught for direct examination?

Not only has radium offspring down to the sixth and seventh generation, but it apparently has ancestors as well. It is only a link in a genealogical chain. The probable discovery of radium's immediate parent was

published less than a month ago by Boltwood. Uranium is thought a remoter ancestor, possibly a great-grandparent.

Accompanying the atomic disintegration of radioactive substances, large quantities of heat are evolved showing vast stores of energy hitherto unknown inside the atom.

The most remarkable explanation yet offered of the observed radio-active phenomena indicates that the complex system of electrons revolving at enormous speeds within the atom gradually loses energy until the configuration becomes unstable. A sudden readjustment takes place—a kind of internal explosion by which electrons or a particles, or both, are hurled out. The atomic structure thus relieved starts life as a new substance with a lower atomic weight. Later the new substance for a like reason again becomes unstable, another explosion occurs, and an atom of yet another substance is born.

If this interpretation of the evidence be accepted a conclusion of vast importance may be drawn. We have, we can not say going on before our eyes, but we may say in a sense going on under our hands, a slow evolution or transmutation of matter. This conclusion is not accepted as yet without reserve, for it strikes too deep at one of the assumptions of our older knowledge. Material atoms have long been thought of as immutably fixed for all time, but so were animal and plant species before Darwin. The growing evidence for this larger view of matter, though recent, is already too strong to be longer ignored. The burden of proof is gradually shifting, and to Alice's question, "Why?" comes back the equally pertinent "Why not?" of the March Hare.

To gather a little together: The electron has but a thousandth part of the inertia of the lightest known material atom, and this inertia it doubtless borrows from the kindly ether and does not hold in its own right. Its behavior is that of an atom of negative electricity pure and simple. Its form is spherical and not spheroidal. Its size is probably less than one ten-million-millionth of an inch. When revolving briskly enough in an orbit within the atom it gives us colored light of highest purity. When violently jostling irregularly about it gives us white light. Without it all light would be impossible.

We believe we have found electricity free from matter, but never yet matter free from electricity. Finally comes the suggestion that matter no less than life may be undergoing a slow but endless evolution.

Some of these things and many others have led physicists to suspect that if all electricity was removed from matter nothing would be left, that the material atom is an electrical structure and nothing more.

There are, however, many stubborn questions to which answers must somehow be found before the so-called electron theory of matter can be accepted unreservedly. As it stands it is at once a most brilliant and promising hypothesis, but has not yet reached the full stature of a theory.

Should it hold good, the material atom with its revolving electrons becomes the epitome of the universe. The architecture of the solar system and of the atom, the very great and the very small, reveals the same marvelous plan, the same exquisite workmanship. The conservation of energy becomes an ethereal law and the ether the abiding place of the universal store of energy.

To end as we began, we have matter and electricity which some day may be one, and ether and energy. Of these we hope some time to build in theory a reasonable world to match the one we now so little understand.

When all the interrelations among matter, ether, electricity are separated out and quantitatively expressed, we believe our work will be complete.

Such, then, is the confession of faith, the very far-distant hope of the modern physicist.

Soldering of Platina.—The soldering of platina vessels that have become damaged is effected either with platina and the oxyhydrogen blowpipe, or with the aid of pure gold. The latter process, however, has the disadvantage that under great heat the gold will melt out and the fissure reopen. It is better, therefore, to apply to the crack a coating of powdered platina mixed with oil of turpentine, heat the spot to a white heat, and weld the crack tight by hammering. Another process consists in hanging a small piece of platina over the crack, provided it is at the edge, fastening it there, and then placing it in the fire until a white heat is produced, upon which the welding together follows. A small hole may be stopped by a small piece of sufficiently thick platina wire, which is riveted to a head on each side and then welded in. For larger holes, a suitable piece of sheet platina is prepared and fastened with rivets, whereupon the welding process is carried out. To fasten several strips of sheet platina together lengthwise, the ends must be bent over, and then welded together; pieces of sheet metal overlapping one another are fastened with rivets and then welded together.

ENGINEERING NOTES.

Sir John Thornycroft, F. R. S., has devised an instrument to indicate the relative rate of turning of two bodies. A sphere supported on two equal revolving cylinders rotates on axes in the same plane as the axes of the cylinders; the angular position of the axis of the sphere depends on the relative velocities of the two cylinders and is indicated by a hand, controlled by a roller touching the sphere.

Consul-General Robert J. Wynne reports that a new tar-spraying machine, which the makers claim will do away with the dust nuisance, has been tested on the roadway in front of the Horticultural Hall, Westminster, London, before practically the whole of the municipal engineers, a large number of county surveyors and suburban engineers, and two representatives appointed by the war office. After the tar-spraying process a second machine scattered a level layer of granite grit and chips upon the tar, which, when rolled, formed a road with a fine, smooth surface, durable and dustless. A tar macadam road made in this way costs from 3s. 6d. to 4s. (85 to 97 cents) a square yard, as against ordinary macadam, which costs on an average 2s. 6d. (60 cents) a square yard.

A British patent has been taken out by Black & Lennox on machinery for drying coal, coke, slag, and other materials. The apparatus consists of two concentric vertical cylindrical casings, the inner one being mounted on bearings and rotated from above by suitable gearing and provided with horizontal shelves, spaced apart, which extend to, but do not touch the outer casing, and divide the annular space into superposed compartments. The material is fed on to the top shelf through a hopper placed at the side, and is spread out in an even layer by a plate fixed tangentially to the inner cylinder. It is carried round as the shelf rotates and then discharged by a scraper plate, also fixed tangentially to the inner cylinder, on to a shoot fixed in a vertical box which connects the first with the second shelf. From the box the shoot discharges the material on to the second shelf. In this way the material is caused to pass round each shelf and from shelf to shelf, till it reaches the lowest, from which it is discharged. Hot air or gas is introduced below the lowest shelf and passes round, in the opposite direction to the material, on to which it is deflected by partitions, and rises from shelf to shelf by external connecting pipes.

Many tests which have been made appear to show that some economy results from the use of live steam in feed-water heating, but it is difficult to see how any saving can be effected by taking live steam from a boiler and immediately returning it thereto when mixed with feed-water. There are indirect advantages in this method, but they consist for the most part in greater uniformity of working, the avoidance of straining, and in the consequent saving of wear and tear on the boilers. An exhaustive test was recently made by Prof. John Goodman and Mr. D. R. MacLachlan on a 14-foot return tubular boiler, 96 inches in diameter, having 60 3-inch tubes and two 6-foot furnaces each 30 inches in diameter. This boiler was tested for 12 hours at an output of 5,000 pounds of steam per hour, both with and without the live-steam heater. The results of the two tests, as given in a paper read before the Institution of Mechanical Engineers, show that the boiler evaporated almost exactly the same quantity of water per pound of coal both when the heater was in use and when not in use. The only advantage discernible from the use of the heater was that the deposit in the boiler was materially less when the heater was used than when the feed water passed direct to the boiler.

Veyrat and De Vaux are the inventors of a continuous dryer for materials liable to be damaged by too high a temperature or by impurities. The materials to be dried are fed through a chute into a horizontal drying tube, which is supported on rollers, and rotated by any suitable means. The material is moved forward in the tube by scrapers, and is finally discharged at the farther end into a trough, from which it is removed by a screw conveyor. Products of combustion from a furnace pass through a series of gilled tubes constituting an air heater, and then through a tube fixed eccentrically within the drying tube. From the farther end of this inner tube, the gases pass into a closed chamber, and then return through an underground flue into a chamber surrounding the central part of the drying tube, from which they are withdrawn by a fan. Air passes through the space between the double walls of the furnace, then over the gilled heating pipes of the air heater, through a chamber surrounding the inlet end of the drying tube, and finally over the material in the drying tube, being withdrawn, along with the vapor given off, by a second fan. Any material which has become attached to the outside of the inner tube is removed by brushes fixed to the inner wall of the drying tube. As the inner tube is mounted eccentrically to the outer tube, the brushes only touch the surface of the former for a short time and do not wear out quickly.

TRADE NOTES AND FORMULÆ.

Quick-Drying Coach Varnish.—Make a solution of 1 part of Zanzibar copal and 0.75 part of linseed oil, and dilute the mixture with 3 parts of turpentine oil.

A Recipe for a Good Grafting Wax.—Melt 2 kilogrammes of pine resin by heating it slowly (not on an open fire); add 2 tablespoonfuls of linseed oil and 100 grammes of Carnauba wax or beeswax; then take the fluid mass from the fire, and when cold pour into it 300 grammes of about 90 per cent alcohol, previously warmed by placing in warm water.

Wall Paper Suitable for Cleaning.—To render wall paper adaptable for washing with soap and water without destroying the colors, make a solution of 2 parts of borax and 2 parts of stick lac, shellac, or other lac in 24 parts of hot water. Strain the solution through a fine cloth filter and coat the paper with it several times, rubbing the latter with a soft brush after every application till a brilliant polish is obtained. It is immaterial whether the paper is already pasted on the walls or still in rolls.

Rust Paper for Cleaning Articles of Fine Steel.—Wash some pumice in water, powder it fine and mix linseed-oil varnish with the powder. Apply several coatings of this mixture with a brush to good, firm paper, and after the paper has been dried in the air, pass it between smoothing rollers. The following cleaning powder is also recommended: Mix 16 parts by weight of tin putty with 8 of prepared hartshorn, and rub the mixture to a paste with 32 parts of alcohol. The mixture can then be used for cleaning steel articles. Very rusty steel and iron articles should first be washed with hydrochloric acid diluted with an equal quantity of water, and afterward with pure water, then dried, coated with oil, left for a few days, and finally cleaned with the cleaning powder already described. Finely powdered emery with a little olive oil can also be recommended.—Der Industrielle Geschäftsmann.

Acid-Proof Cloths.—It has been found extremely desirable in practical chemistry to have cloths available which are not subject to the action of acids or alkalies. A few years ago, according to the Süddeutsche Apothekerzeitung, a process was patented by Hering, consisting in steeping cotton cloth first in strong nitric acid, and then in concentrated sulphuric acid. The Elberfeld dye factories made use of the process and obtained valuable nitrated cloths, the fibers of which contained from 12.4 to 12.9 per cent of nitrogen, according to the strength and compactness of the thread and tissue. Hexanitrate of cellulose was said to have 14.15, pentanitrate 12.76 per cent. A substance the fibers of which have a tearing resistance in the tissue of over 150 kilogrammes to a width of 100 millimeters, shows the same capacity after nitration; hence it has suffered no loss of strength by the process. This nitrated filtering cloth, the flashing point of which is about 170 deg. C., is very constant in its capacity for resisting the action of concentrated acids and also of chlorine solutions up to a temperature of 50 deg. C. Fabrics made of nitrated cellulose after it had been spun into threads, have hitherto been little offered for sale; a sample showed a smaller content of nitrogen, viz., only 10.9 per cent, and little tensile strength, tearing when subjected to a weight of 85 to 90 kilogrammes. Moreover, it dissolved readily in concentrated sulphuric acid, and had also little capacity for resisting the action of chlorine; for ordinary filtering purposes it had the disadvantage of being too porous. Consequently, the above-quoted journal remarks, not only is our present technical knowledge able to make cloths nitrated throughout directly from cotton, but these fabrics are far superior to cloths woven from spun nitrocellulose, not only in regard to their degree of nitration and tensile strength, but also in regard to simplicity and cheapness of production, and especially to their value as filtering cloths for chemical purposes.

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